MSC-03909

HABITABILITY DATA HANDBOOK

VOLUME 6

PERSONAL HYGIENE

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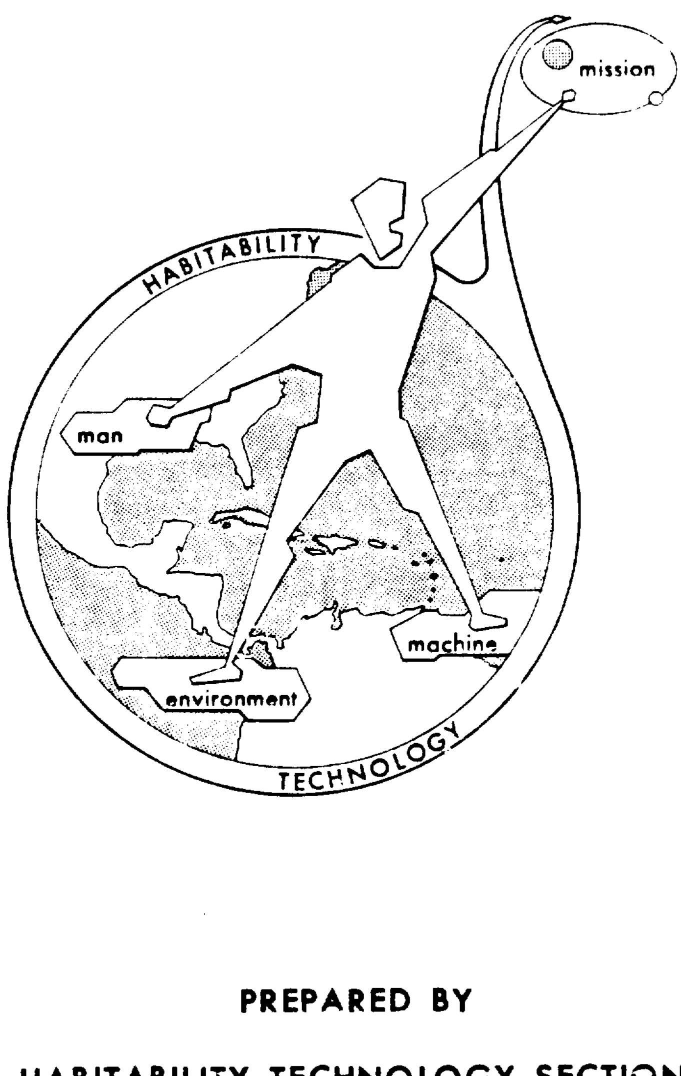

PREPARED BY

HABITABILITY TECHNOLOGY SECTION

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PREFACE

The Habitability Data Handbook is a collection of data in six volumes which include requirements, typical concepts, and supporting parametric data. The handbook provides an integrated data source for use in habitability system planning and design, intersystem trade-offs, and interface definition. The following volumes comprise the Habitability Data Handbook:

Volume	Title
1	Mobility and Restraint
2	Architecture and Environment
3	Housekeeping
4	Food Management
5	Garments and Ancillary Equipment
6	Personal Hygiene

This volume provides data for personal hygiene systems applicable to extra-terrestrial habitats and vehicles.

These data are considered preliminary and are predominantly derived from analytical and terrestrial sources and in general lack zero-g verification.

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CONTENTS (CONCLUDED)

1.0 INTRODUCTION

1.1 PURPOSE

This Personal Hygiene volume was developed to provide handbook data for use by space systems planners, designers, system engineers and habitability system engineers. This handbook provides a technology base which includes recognition of requirements, and presentations of concepts with supporting data. By providing new personal hygiene concepts which are applicable to long-duration manned spacecraft, the handbook also establishes a basis for areas requiring future development.

The document integrates habitability technology in handbook format for the following personal hygiene functions:

Urine, Feces and Vomitus Collection	Personal Care and Grooming
Urine collection and processing	Full body cleaning
Feces collection and processing	Local body cleaning
Urine and feces specimen collection and processing	Body drying
Anal cleansing	Hair cutting
Vomitus collection and processing	Shaving
	Nail care

1.2 MAJOR INTERFACE AREAS

The personal hygiene systems interface with the following habitability areas:

- Housekeeping (Volume 3)
- Architecture and Environment (Volume 2)
- Mobility and Restraint (Volume 1)
- Garments and Ancillary Equipment (Volume 5)

The processing of personal hygiene waste materials, which include feces, urine, hair, and human contaminants in water, is discussed in the Housekeeping volume.

The Architecture and Environment volume provides design considerations and requirements for facilities required to accommodate personal hygiene activities.

The Garments and Ancillary Equipment volume describes washing techniques for towels and wipes used in personal care. The Mobility and Restraint volume defines requirements and techniques for body restraint.

1.3 HANDBOOK USE

To obtain methods for accomplishing a specific function, e.g., feces collection and processing, locate the function in the applicable section (Urine, Feces and Vomitus Collection and Cleaning - Section 3, or Personal Care and Grooming - Section 4). The following information is provided for each function:

a) Requirements
b) Concept descriptions
c) Engineering data for each concept.

The concept descriptions will normally include a schematic diagram. The engineering data includes such parameters as weight, volume, power, and spares quantities. The parameters are presented in equation form and a graphic presentation is provided for each equation that does not represent a single linear function. The equations presented in the engineering data are repeated on the graphic representation as shown in Figure 1-1. The symbols used in the equation are defined in the abscissa and ordinate to clarify their usage.

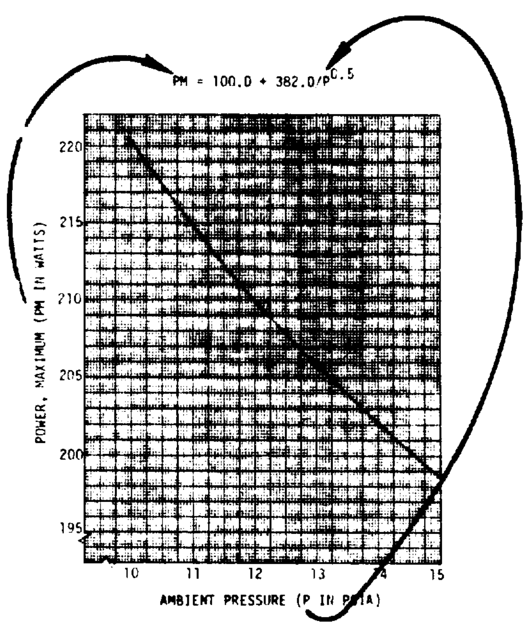


Figure 1-1. Sample Graphic Presentation

All acronyms and abbreviations used in the engineering data are defined in the Nomenclature List provided below. Supporting theoretical analyses for the detailed engineering data are provided in Appendix A.

1.4 NOMENCLATURE

A	=	Area, cross sectional flow, ft^2
a	=	Acceleration, ft/sec^2
AL	=	Atmosphere Lost to space, lb/day
C	=	Crew size, number of men
COP	=	Coefficient of Performance
C_p	=	Heat Capacity at constant Pressure, Btu/lbm-°R
D	=	Diameter, units specified
EV	=	Expendable Volume, ft^3/day
EW	=	Expendable Weight, lb/day
FV	=	Fixed Volume, ft^3
FW	=	Fixed Weight, lb
h_{fg}	=	Latent heat of vaporization of H_2O
L	=	Length of specimen collection period, days
LL	=	Laundry Load, lb of wash/day
N	=	Quantity of units, number of units
P	=	Pressure, ambient, psia
PA	=	Power, Average, watts-hours/day
PC_R	=	Pretreatment Chemical Usage Rate
PM	=	Power, Maximum, watts
PM_{HP}	=	Maximum Power of Heat Pump
PR	=	Processing Rate
Q	=	Air flow rate, CFM
Q_{CA}	=	Cooling from atmosphere, Average, Btu/day
Q_{CP}	=	Cooling from atmosphere, Peak, Btu/minute
Q_H	=	Heating required from atmosphere, Btu/day
Q_{LA}	=	Cooling from Liquid loop, Average, Btu/day
Q_{LP}	=	Cooling from Liquid loop, Peak, Btu/minute
R	=	Resupply interval, days
Rho	=	Density of metal, lb/in^3
S	=	Number of specimen collection subjects (number of men participating)

SI	=	Weight of Initially Launched Spares, lb
SR	=	Weight of Spares required per Resupply period, lb
SW	=	Spares Weight
T	=	Temperature
t	=	Thickness of metal, inches
VU	=	Vacuum cleaner Usage rate, hours/day
WE	=	Water Effluent to WMS, lb/day
WI	=	Water Influx from WMS, lb/day
WL	=	Water Lost to space, lb/day
WMS	=	Water Management System
WV	=	Water Vapor rejected to atmosphere, lb/day

2.0 PERSONAL HYGIENE GENERAL REQUIREMENTS

The following general requirements apply to all personal hygiene subsystems. Detailed requirements relative to individual personal hygiene functions and associated equipment are provided with the concept descriptions and engineering data in Sections 3 and 4.

- Function and use of systems should require minimum familiarization or training.
- Systems shall allow for simultaneous defecation and urination.
- Systems shall be oriented so that use is as on earth (e.g., defecation in a sitting position).
- Maximum noise generated by personal hygiene equipment should not exceed 90dB, a 65dB limit is preferable.
- Personal hygiene equipment should be designed to minimize crew time required for use, operation, and maintenance.
- Proper personnel restraints should be provided.
- Man-to-man microbial cross contamination shall be avoided in all personal hygiene functions.
- The personal hygiene system shall preclude return of odors, particulates, biotic contaminants, or toxic gases to the spacecraft atmosphere.
- There shall be no hard-line cross-connections between the waste management system and the crew's potable water system upstream of the processing equipment.
- Expendables (e.g., strong acids, powders, and aerosols) shall neither support combustion nor be hazardous to the crew or equipment.
- Crewmen must be protected against contact with devices whose temperature exceeds 145°F for momentary contact or 110°F for continuous contact.
- Refuse containers should cause no back contamination to the cabin, and should minimize biological activity (if not taken care of in the disposal procedure).

3.0 URINE, FECES AND VOMITUS COLLECTION AND CLEANING

3.1 URINE COLLECTION AND PROCESSING

3.1.1 Requirements.

- The capacity to collect urine shall be as follows:

amounts:	1.1 lb per urination maximum, 0.88 lb/use nominal
frequency:	3 to 7 urinations per man-day, 5 nominal
quality:	pH; 4.5 to 8.0 specific gravity; 1.002 to 1.035, 1.01 nominal
constituents:	electrolytes, nitrogen compounds, vitamins, acids, organic compounds, hormones

- At the time and point of collection, urine should be pretreated for suppression of bacteria and ammonia.
- The system shall be capable of processing urine which has been treated for the suppression of ammonia generation and bacteria growth.
- Microbial activity shall be permanently eliminated except in the case of biological treatment units.
- The capacity to process urine shall be as follows:

amounts:	7.7 lb/man-day maximum, 4.4 lb/man-day nominal
frequency:	3 to 7 urinations per man-day, 5 nominal
quality:	pH; 4.5 to 8.0 specific gravity; 1.002 to 1.035, 1.01 nominal

- Any residue from the processing equipment should be prepared for storage.
- Sensory (visual, olfactory, and tactile) isolation from collected urine shall be provided.
- The collection process shall not expose personnel to the space environment.

3.1.2 Concept Descriptions and Engineering Data.

The urine collection and processing concepts discussed in this section are: a) the Penis Seal Urinal, b) the Aperture Urinal, and c) the Urine Collection Module.

Penis Seal Urinal (Figure 3-1)

The seal unit is attached via a flexible hose assembly to a centrifugal separator. A blower is employed to draw cabin air through the urinal, hose and separator. Urine expelled into the urinal is transported through the hose to the motor-driven centrifugal separator where a rotating vaned drum creates a centrifugal force on the urine. The urine droplets are spun radially outward from the center of the drum to a rotating gutter. A stationary pitot tube collects the urine from the rotating gutter. The velocity head at the pitot tube is converted to a static head, and the urine flows out of the separator and is pumped into the water management system. After passing the separator, cabin air flows through a bacteria filter, an odor control filter, and then past the blower and back to the cabin.

Each crewman is provided with a supply of individual diaphragms which can be attached to the seal unit for use. The seal unit has a provision for size adjustment. The penis is inserted and a seal is created by the diaphragm to the penis just behind the glans. After urination, the penis is withdrawn, the diaphragm removed, and the unit is stowed with its sealing cap on. Water is injected into the unit to clean the hose and separator. After the flush, the separator and blower are turned off.

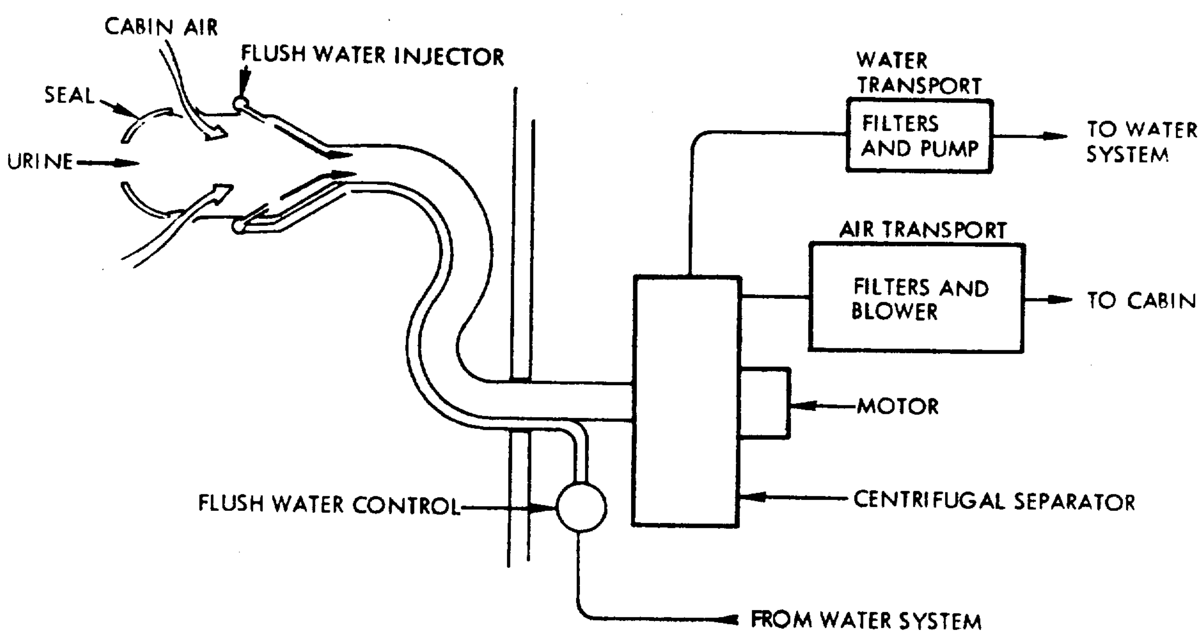


Figure 3-1. Penis Seal Urinal

Penis Seal Urinal Engineering Data

Fixed Weight (FW in lb)			Figure 3-2
Seal and hose		3.0N	
Separator		5.0N	
Water transport		5.0N	
Air transport			
Fan	4.0N		
Canister	2.5N		
Filter housing	1.0N		
Structure	0.75N		
Duct	$1.3N/P^{0.25}$		
(See Appendix A)		$(8.25+1.3/P^{0.25})N$	
	Total FW =	$(21.25+1.3/P^{0.25})N$	
Fixed Volume (FV in ft^3)			
Air transport		1.25N	
Separator		0.5N	
Water transport		0.5N	
Seal and hose		0.5N	
	Total FV =	2.75N	
Expendable Weight (EW in lb/day)			
Odor cartridges		0.033C	
Bacteria filters		0.0011C	
Diaphragms		0.0083C	
	Total EW =	0.0424C	
Expendable Volume (EV in ft^3/day)			
Odor cartridges		0.00125C	
Bacteria filters		0.0000167C	
Diaphragms		0.0000945C	
	Total EV =	0.00136C	
Power, Maximum (PM in watts)			Figure 3-3
Pump		10	
Separator		20	
Fan		$208/P^{0.5}$	
	Total PM =	$30+208/P^{0.5}$	

Power, Average (PA in watt-hrs/day) Figure 3-4

PA = (hrs used per man-day)(PM)(C)

$PA = 0.1\ (30+208/P^{0.5})C$

$PA = (3+20.8/P^{0.5})C$

Water Influx from WMS (WI in lb/day)

WI = 6.0C flushes per day (1.0 lb/flush)

WI = 6.0C

Water Vapor rejected to atmosphere (WV in lb/day)

$WI\ (T_1-T_2)\ C_p$ + urine rate $(T_1-T_2)\ C_p = h_{fg}\ WV$

$6C\ (160-70) + 4.4C\ (100-70) = 1100\ WV$

$\underline{WV = 0.61C}$

Water Effluent to WMS (WE in lb/day)

$WE = WI$ + urine rate $-WV$

$WE = 6C + 4.4C - 0.61C$

$\underline{WE = 9.79C}$

Cooling from atmosphere, peak (Q_{CP} in Btu/minute) Figure 3-5

$Q_{CP} = 0.034\ PM_F$ (PM_F = maximum power of fan, see Appendix A)

$Q_{CP} = 0.034\ (208/P^{0.5})$

$\underline{Q_{CP} = 7.1/P^{0.5}}$

Cooling from atmosphere, average (Q_{CA} in Btu/day) Figure 3-6

Q_{CA} = (minutes used per day)Q_{CP}

$Q_{CA} = 6C\ (7.1/P^{0.5})$

$\underline{Q_{CA} = 42.6C/P^{0.5}}$

Initial and resupply period spares weight (SI and SR in lb) Figures 3-7 and 3-8

See Appendix A for equations and variables

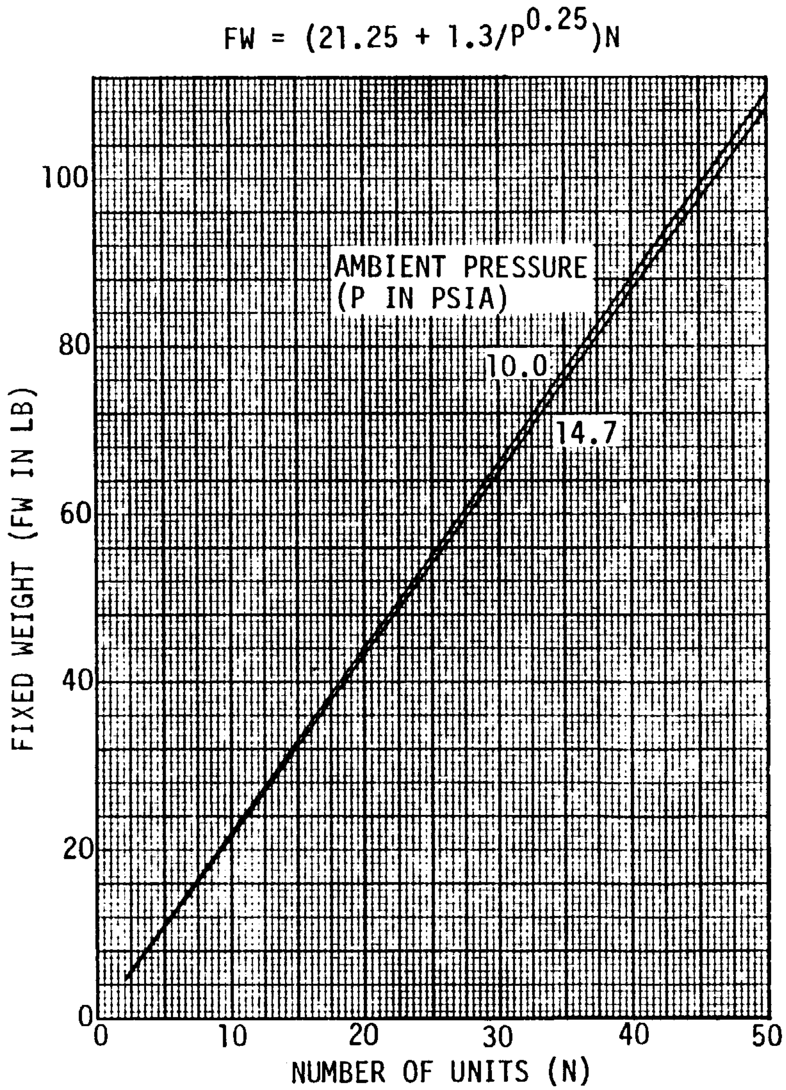


Figure 3-2. Penis Seal Urinal Fixed Weight

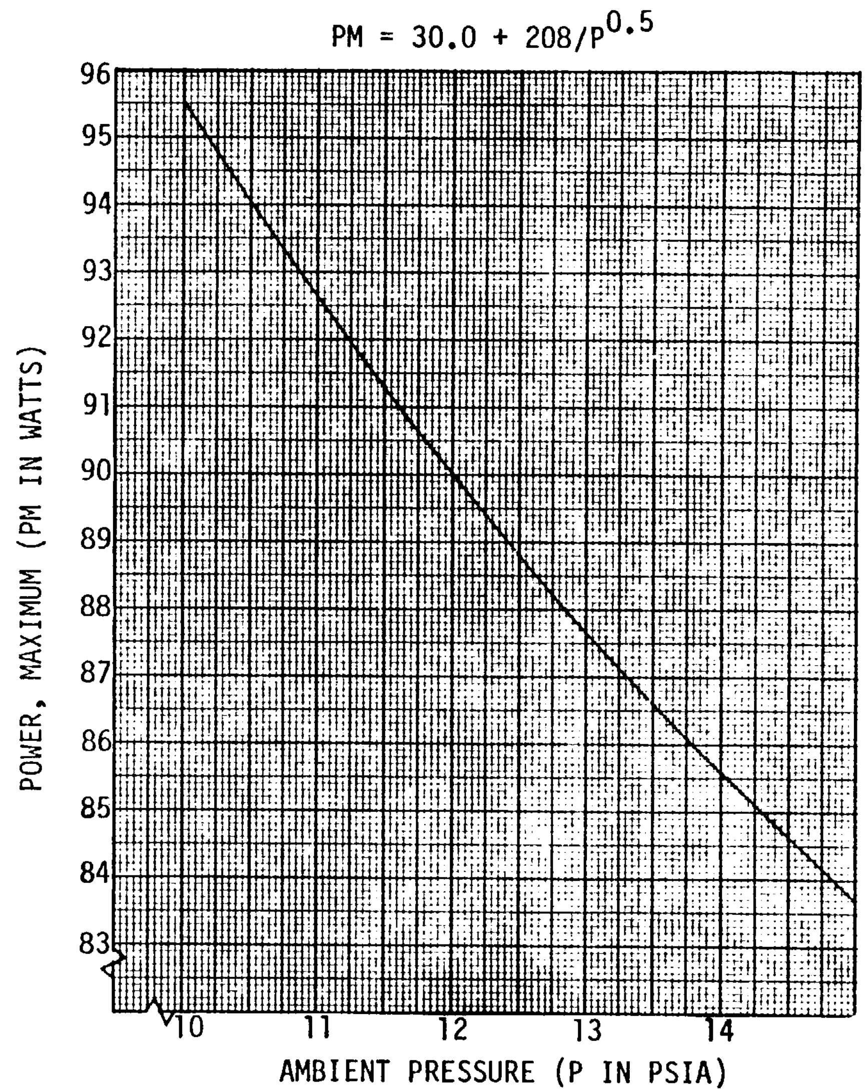


Figure 3-3. Penis Seal Urinal Power, Maximum

$PA = (3 + 20.8/P^{0.5})C$

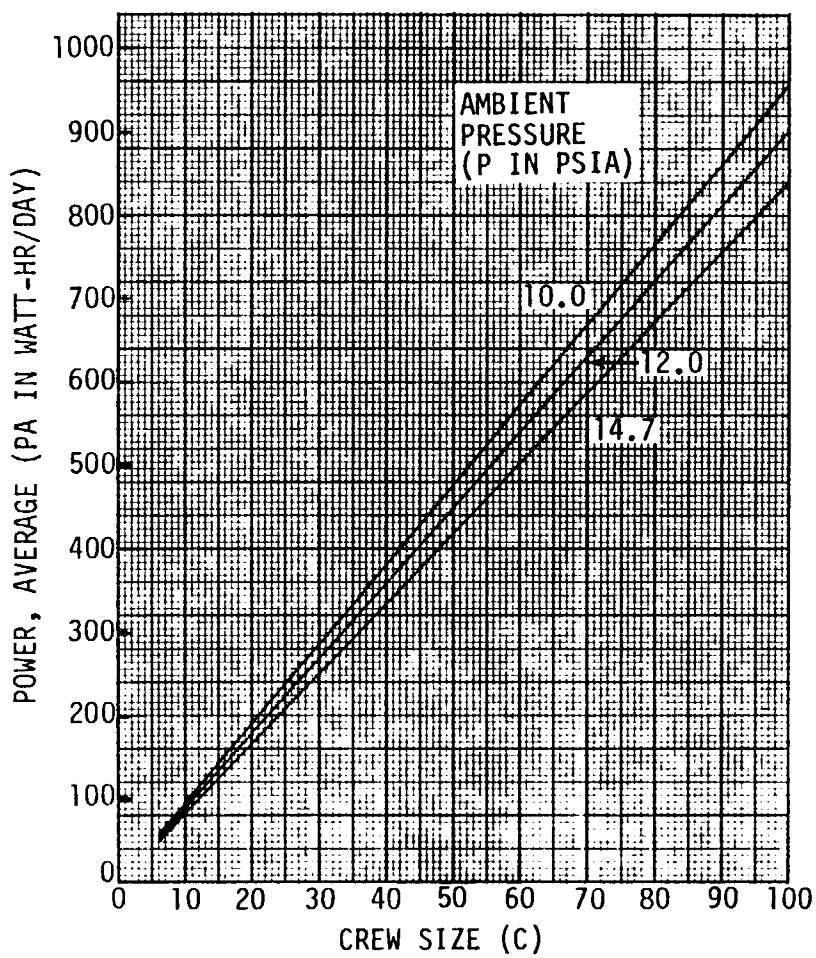


Figure 3-4. Penis Seal Urinal Power, Average

$Q_{CP} = 7.1/P^{0.5}$

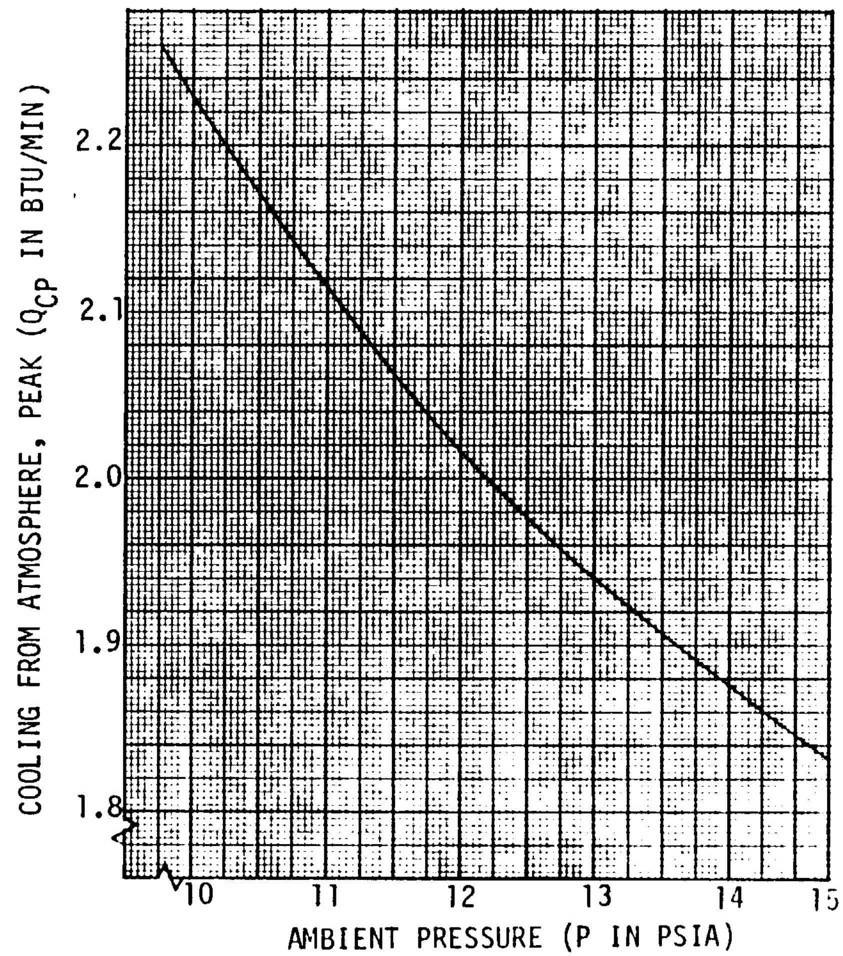


Figure 3-5. Penis Seal Urinal Cooling from Atmosphere, Peak

$$Q_{CA} = 42.6C/P^{0.5}$$

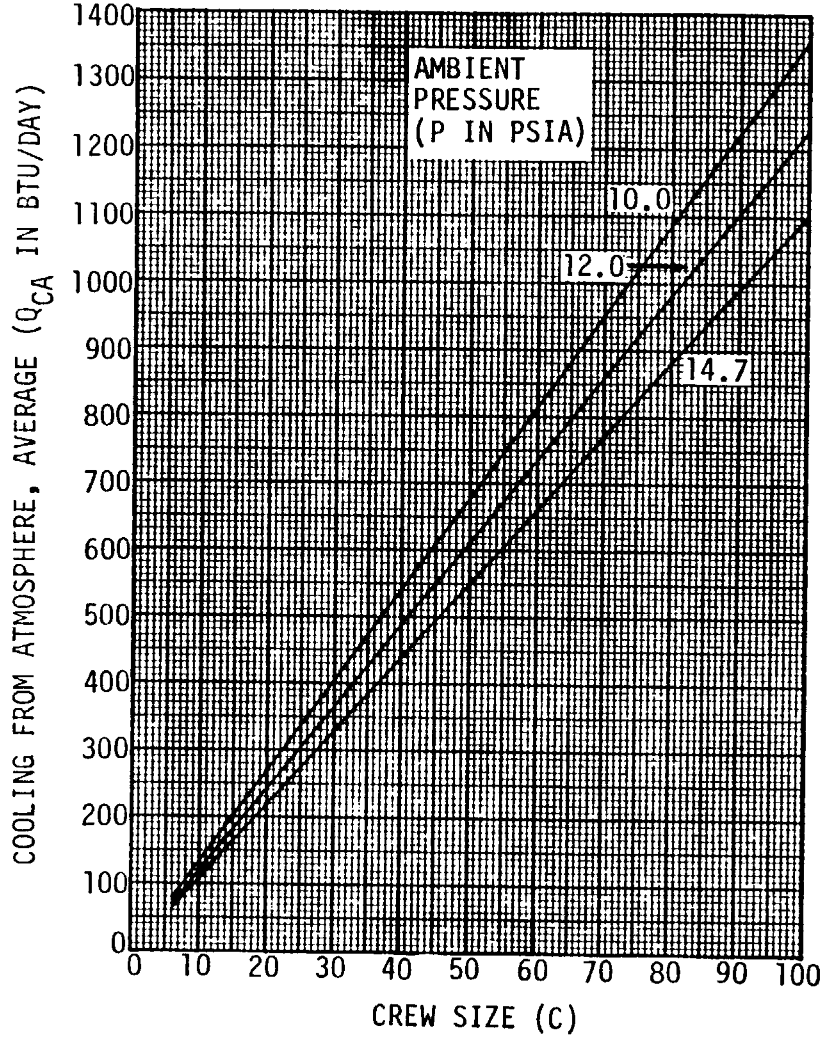


Figure 3-6. Penis Seal Urinal Cooling from Atmosphere, Average

Equation Provided in Paragraph A.6.2 of Appendix A

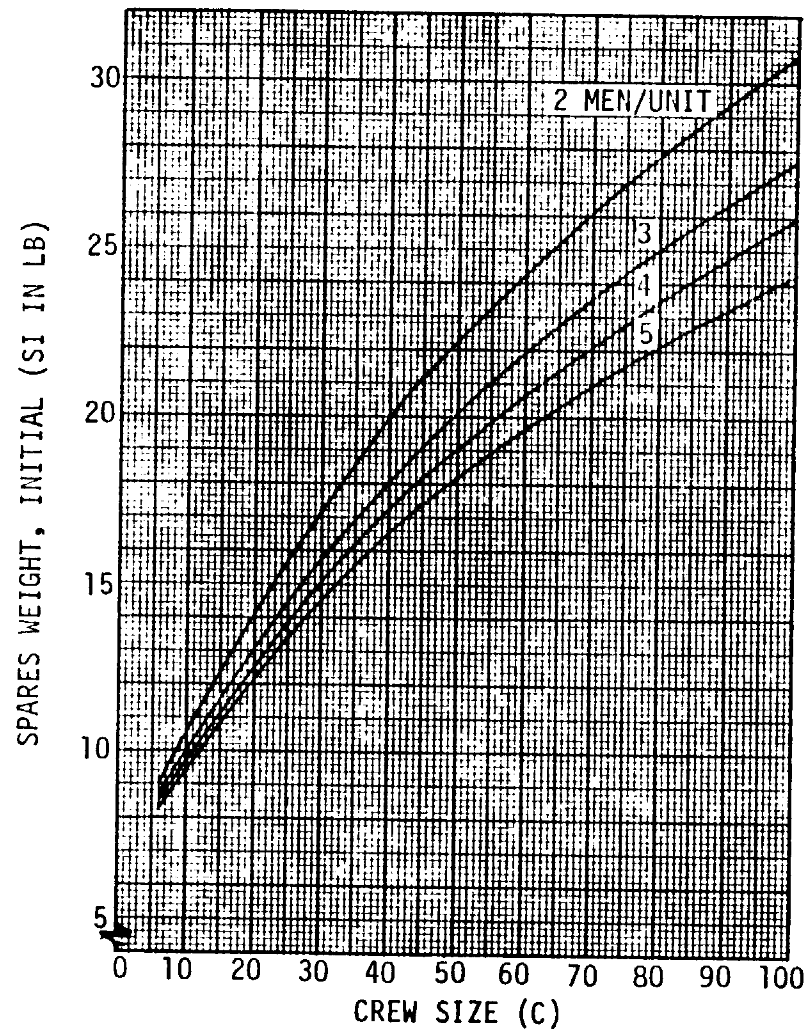


Figure 3-7. Penis Seal Urinal Initial Spares Weight

Equation Provided in Paragraph A.6.3 of Appendix A

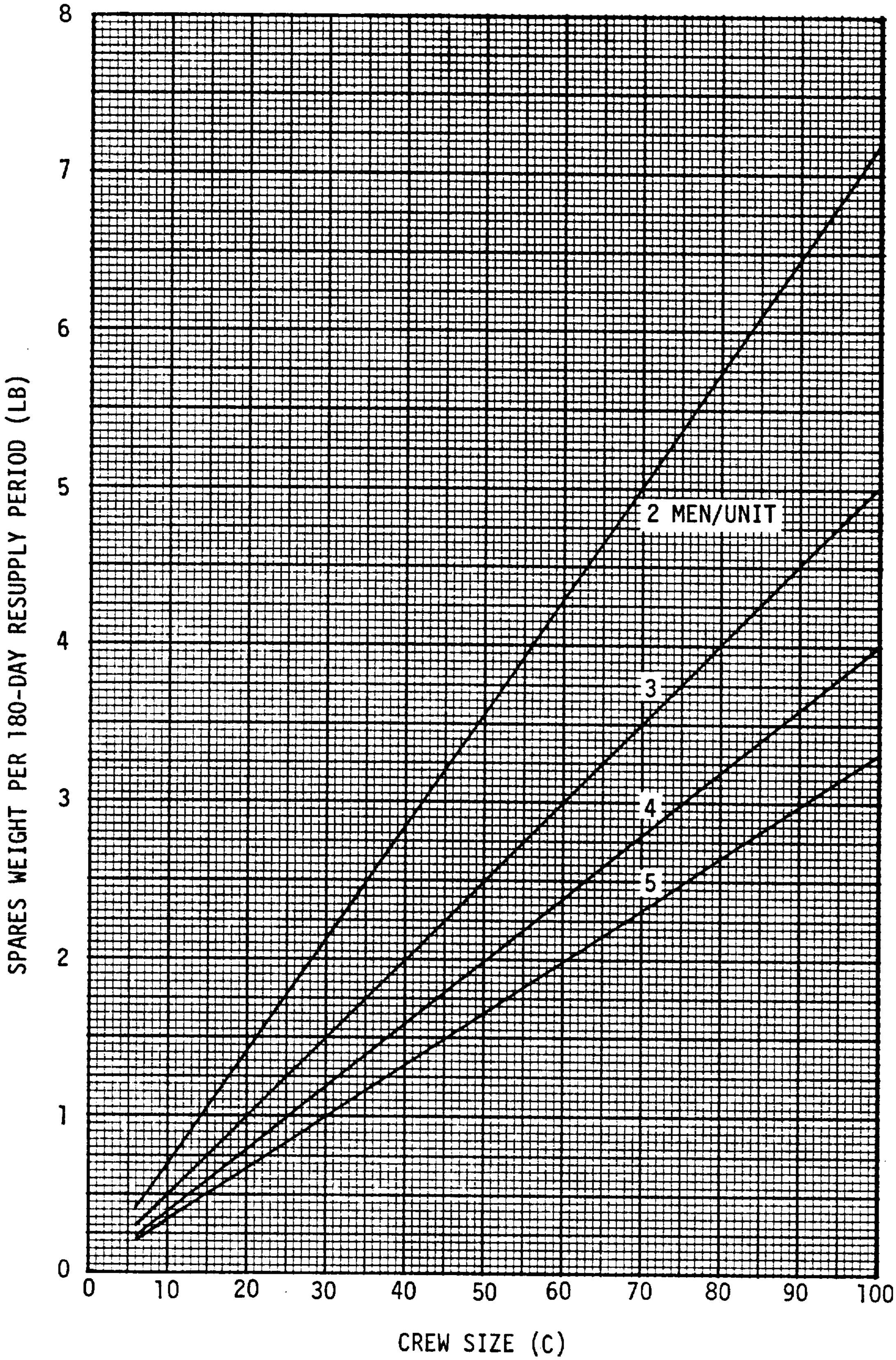


Figure 3-8. Penis Seal Urinal Resupply Period Spares Weight

Aperture Urinal (Figure 3-9)

After the blower and separator are activated, the penis is positioned in front of the aperture (not in contact with the inlet) and the urine stream is directed into the center of the urinal. Air flow from the air transport unit (as described in the Penis Seal Urinal paragraph) is used to control and transport the urine stream to the centrifugal separator. The urine is then separated from the air stream and pumped into the water management system. After urination, the penis is withdrawn, water is injected into the urinal to flush the aperture and the separator, and the blower and separator are shut off.

Aperture Urinal Engineering Data

Figure 3-10

Fixed Weight (FW in lb)		
Aperture cone		3.0N
Separator unit		5.0N
Pump unit		5.0N
Air transport unit		
Fan	3.5N	
Canister	2.5N	
Filter Housing	1.0N	
Structure	0.8N	
Duct	$3.2N/P^{0.25}$	
(See Appendix A)		$(7.8 + 3.2/P^{0.25})N$
	Total FW =	$(20.8 + 3.2/P^{0.25})N$
Fixed Volume (FV in ft^3)		
Air transport unit		1.4N
Pump unit		0.5N
Separator		0.5N
Aperture cone		0.75N
	Total FV =	3.15N
Expendable Weight (EW in lb/day)		
Odor cartridges		0.0333C
Filter elements		0.0011C
	Total EW =	0.0344C
Expendable Volume (EV in ft^3/day)		
Odor cartridges		0.00125C
Filter elements		0.0000167C
	Total EV =	0.0012667C

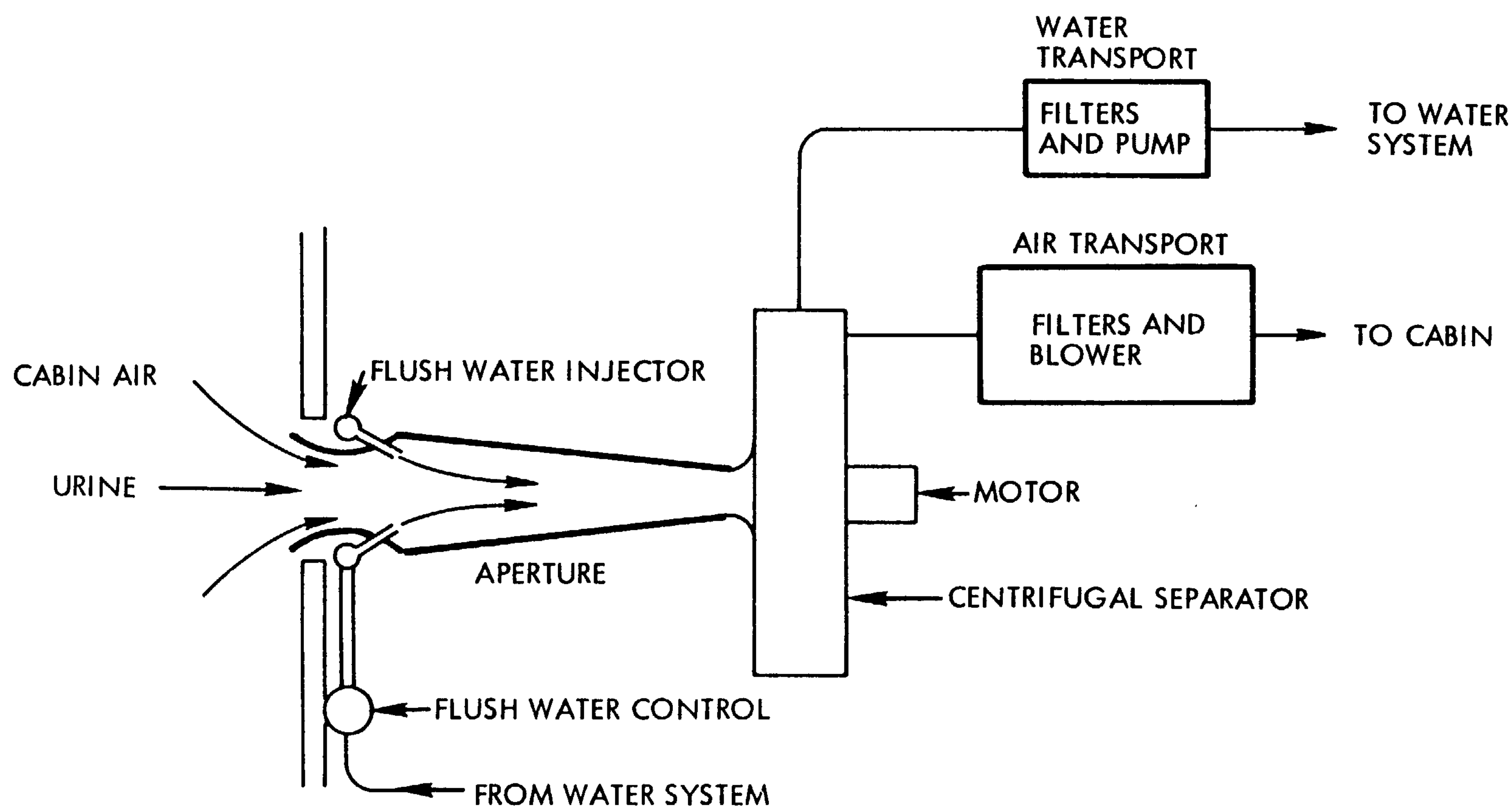


Figure 3-9. Aperture Urinal

Power, Maximum (PM in watts) — Figure 3-11

Pump	10	
Separator	20	
Fan	$890/P^{0.5}$	
Total PM =	$30+890/P^{0.5}$	

Power, Average (PA in watt-hours/day) — Figure 3-12

PA = (use time per day) (PM)

$PA = 0.1C\ (30+890/P^{0.5})$

$PA = (3+89/P^{0.5})C$

Water Influx from WMS (WI in lb/day)

WI = 6.0C flushes per day (1.0 lb/flush)

WI = 6.0C

Water Vapor rejected to atmosphere (WV in lb/day)

$WI\ (T_1-T_2)\ C_p + \text{urine rate}\ (T_1-T_2)\ C_p = h_{fg}\ WV$

$6C\ (160-70) + 4.4C\ (100-70) = 1100\ WV$

WV = 0.61C

Water Effluent to WMS (WE in lb/day)

WE = WI + urine rate - WV

WE = 6C + 4.4C - 0.61C

WE = 9.79C

Cooling from atmosphere, peak (Q_{CP} in Btu/minute) — Figure 3-13

$Q_{CP} = 0.034PM_F$ (See Appendix A)

$Q_{CP} = 0.034\ (890/P^{0.5})$

$Q_{CP} = 30.3/P^{0.5}$

Cooling from atmosphere, average (Q_{CA} in Btu/day) — Figure 3-14

Q_{CA} = use time per day (Q_{CP})

$Q_{CA} = 6C\ (30.3/P^{0.5})$

$Q_{CA} = 181.8C/P^{0.5}$

Initial and resupply period spares weight (SI and SR in lb) — Figures 3-15 and 3-16

See Appendix A for equations and variables

$$FW = (20.8 + 3.2/P^{0.25})N$$

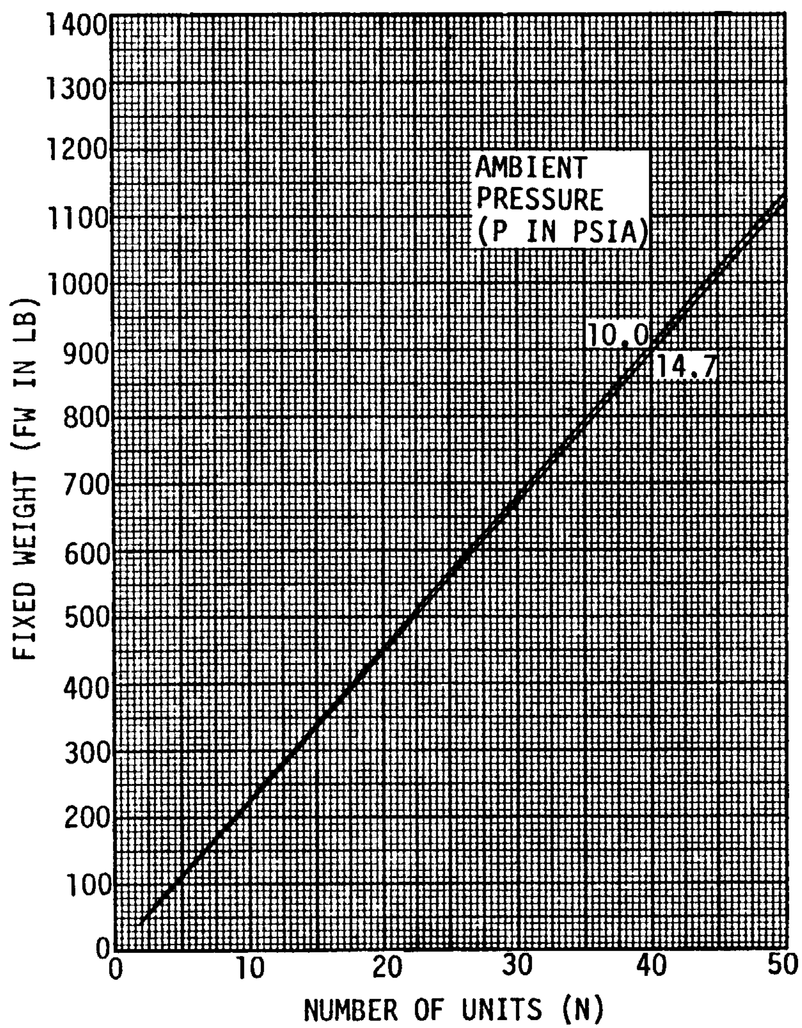


Figure 3-10. Aperture Urinal Fixed Weight

$$PM = 30.0 + 890/P^{0.5}$$

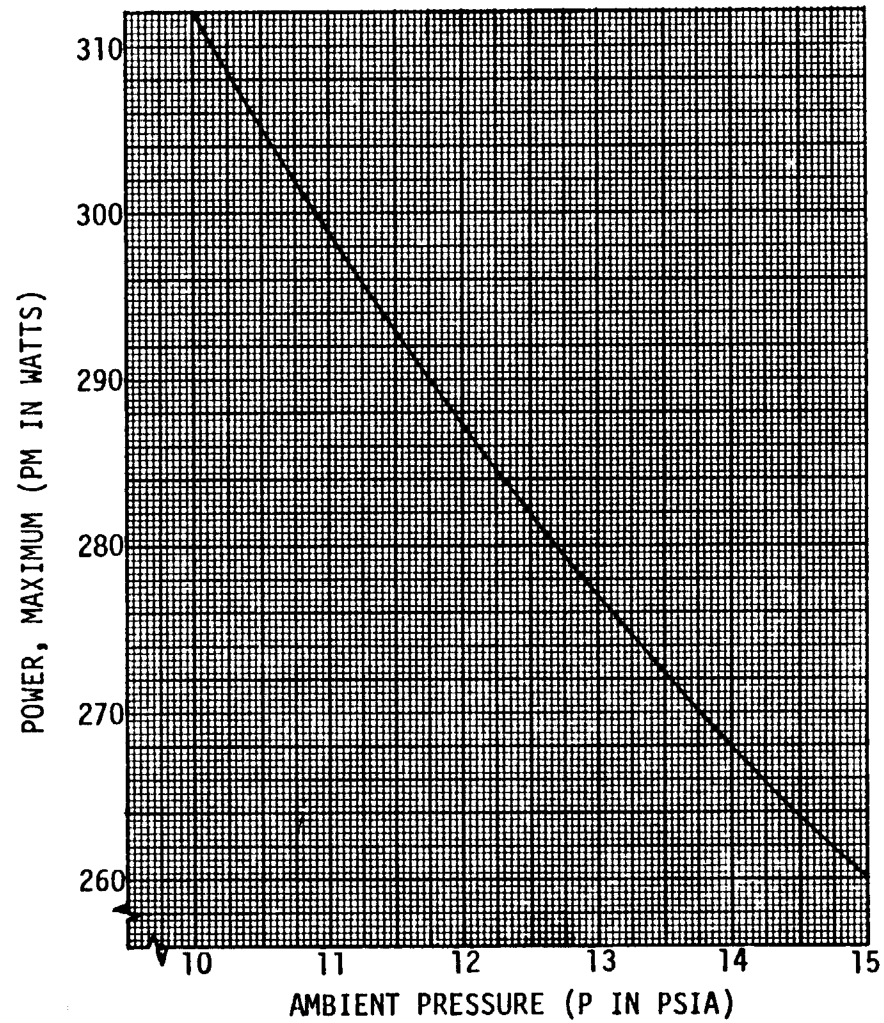


Figure 3-11. Aperture Urinal Power, Maximum

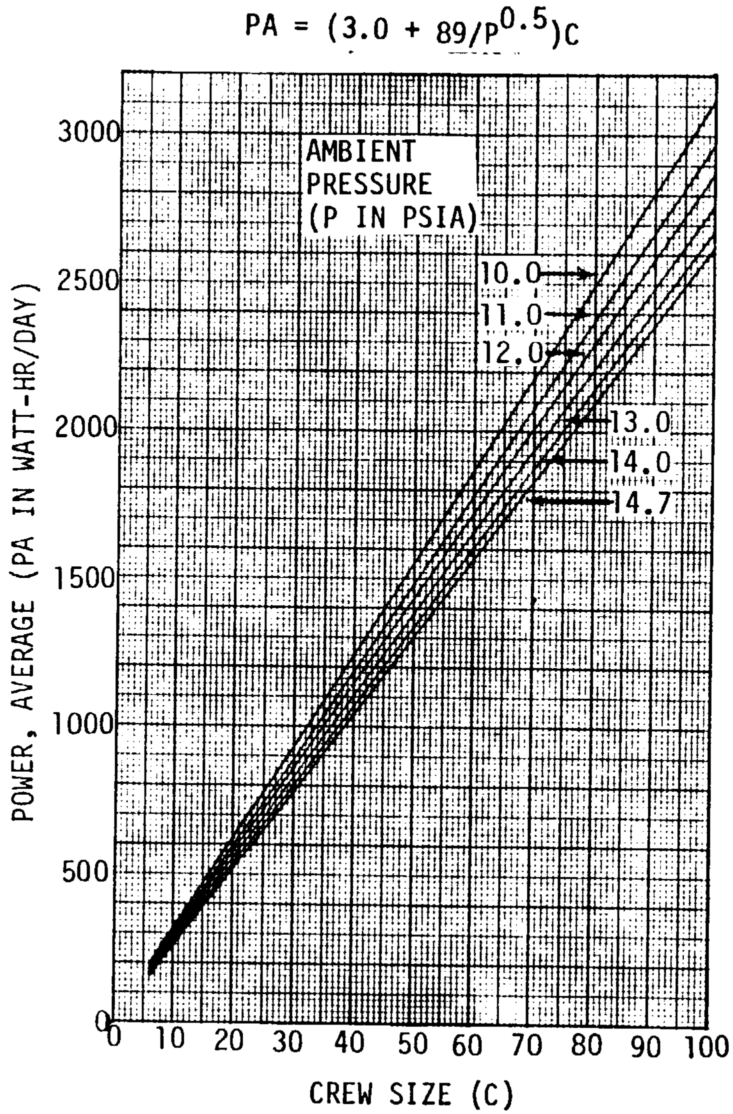


Figure 3-12. Aperture Urinal Power, Average

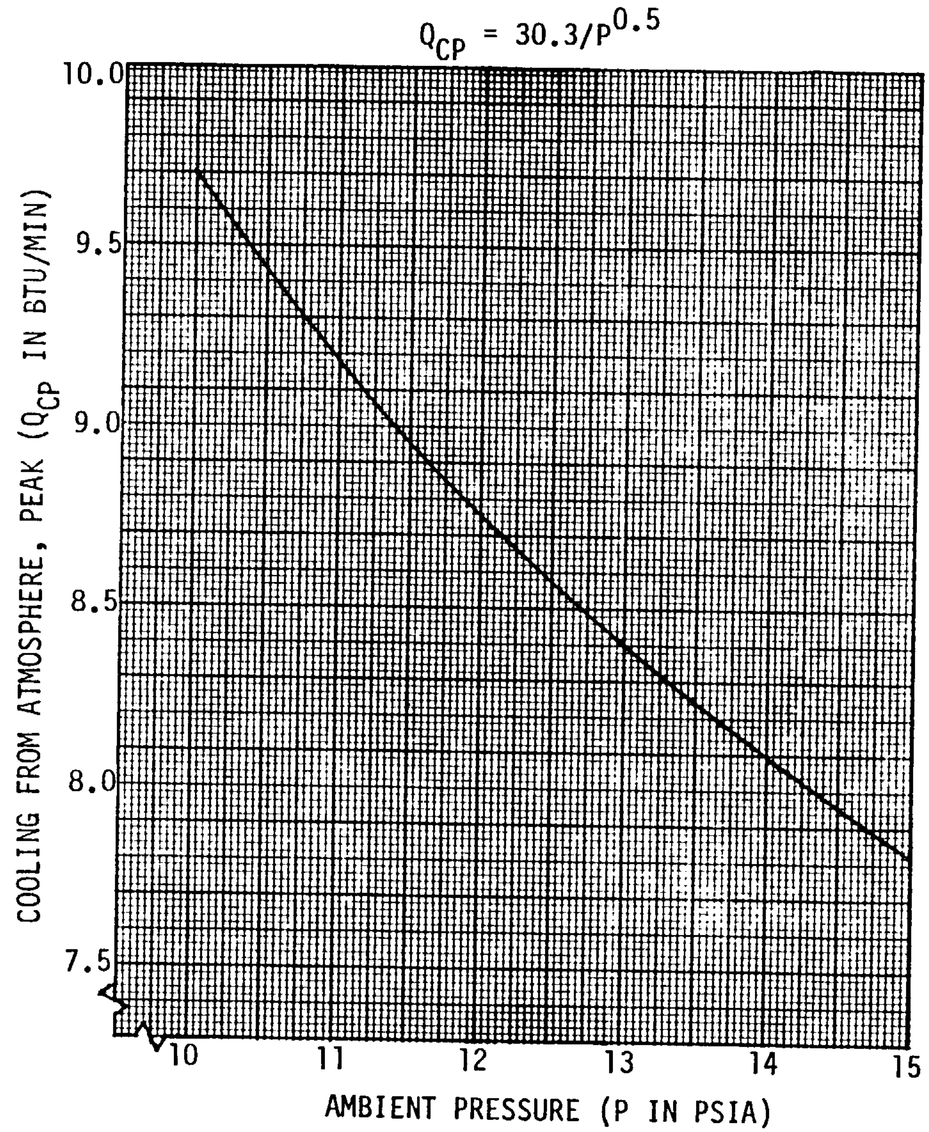


Figure 3-13. Aperture Urinal Cooling from Atmosphere, Peak

$Q_{CA} = 181.8C/P^{0.5}$

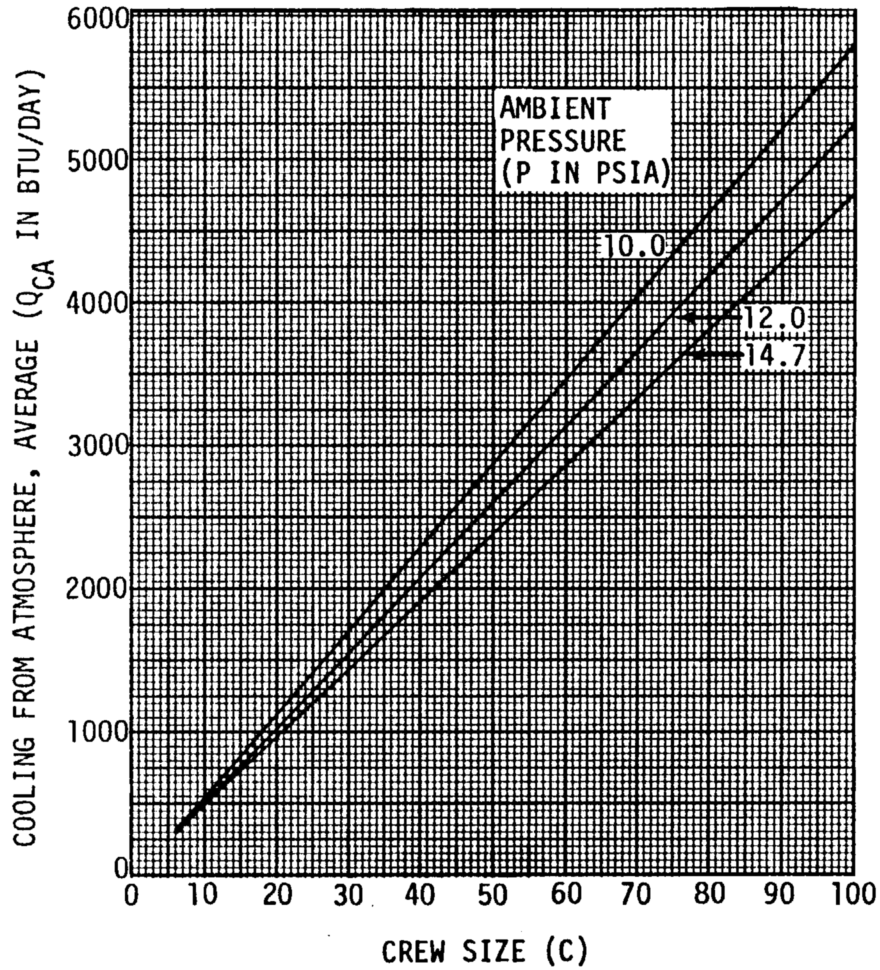


Figure 3-14. Aperture Urinal Cooling from Atmosphere, Average

Equation Provided in Paragraph A.6.2 of Appendix A

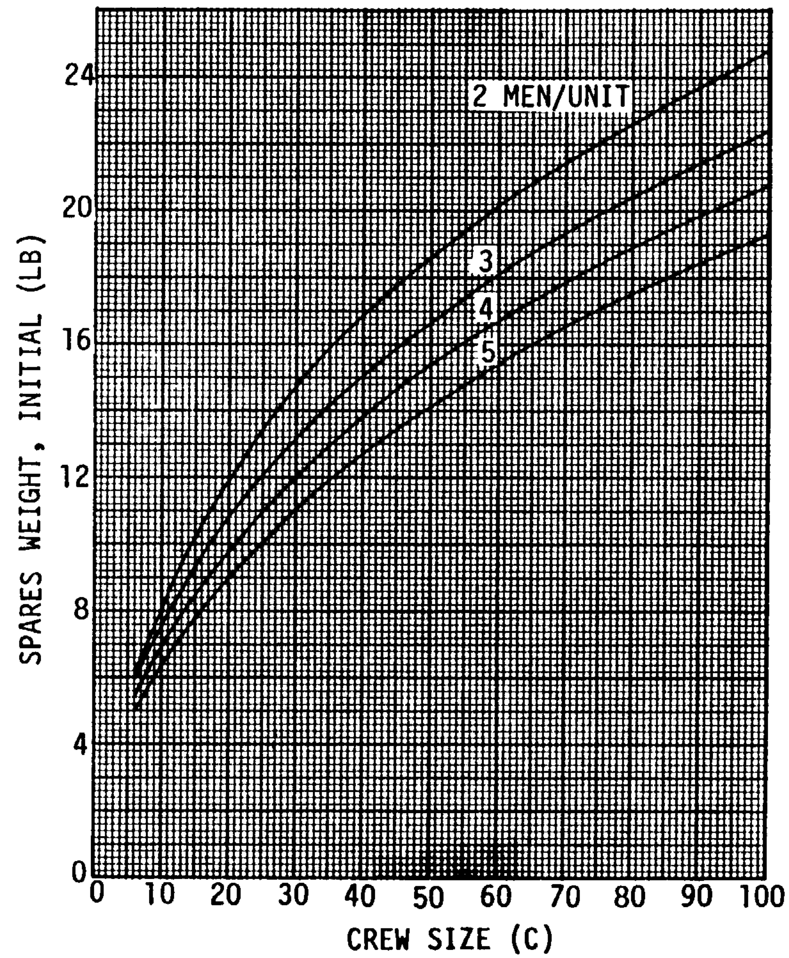


Figure 3-15. Aperture Urinal Initial Spares Weight

Equation Provided in Paragraph A.6.3 of Appendix A

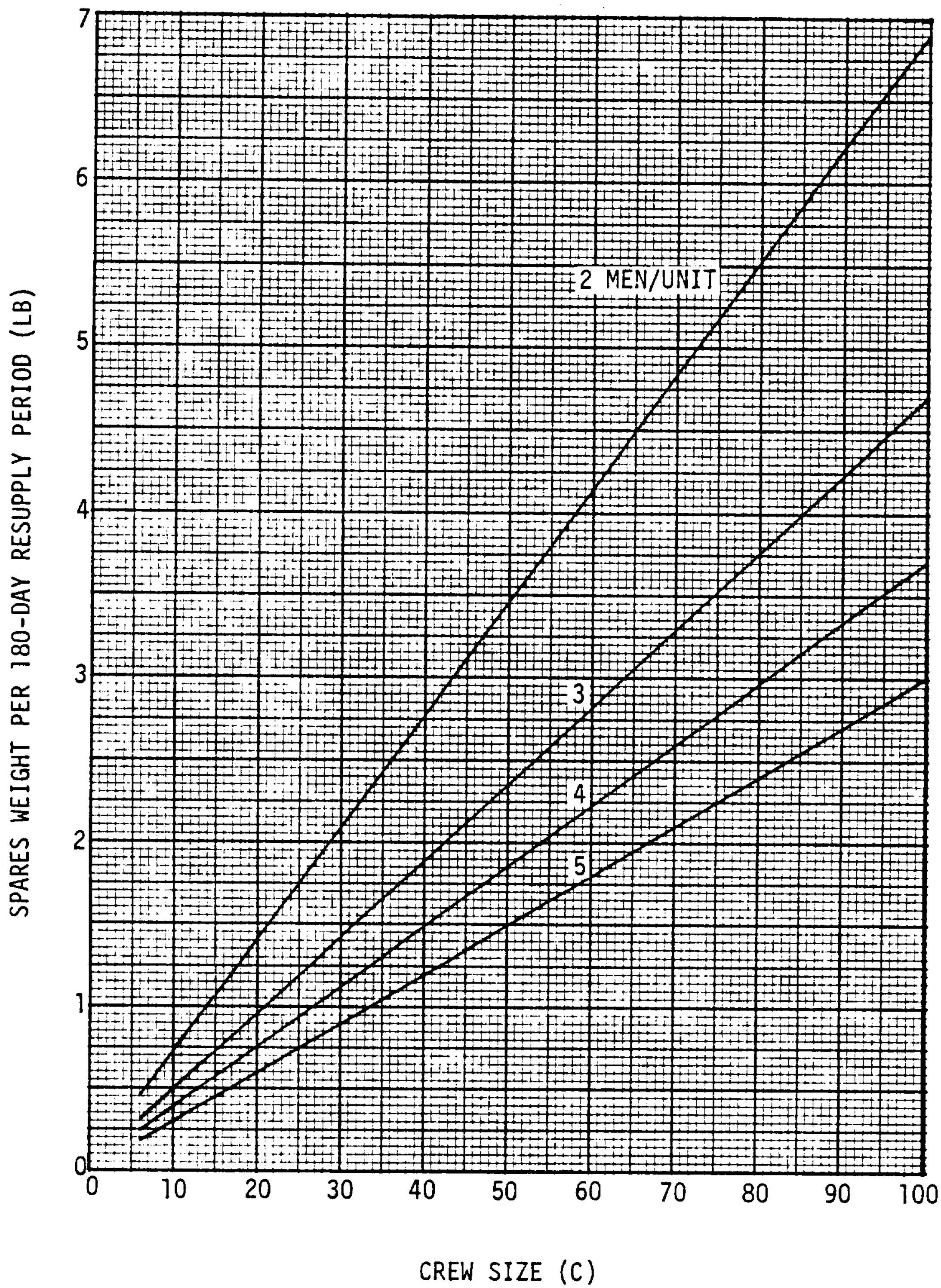


Figure 3-16. Aperture Urinal Resupply Period Spares Weight

Urine Collection Module* (Figure 3-17)

The urine collection module contains a urinal, phase separator, common flush water accumulator/cooler, and flow controls. The urinal has an iris-type opening to avoid backflow during urination. Cabin gas is drawn into the urinal through peripheral holes and transfers the urine to the separator by pneumatic entrainment. A second set of holes provides for rinsing the urinal after use. After urination, the flush solenoid valve is opened to allow silver ion dosed water into the urinal for flushing. The flush water is pressurized at approximately 30 psig and is admitted (by a control timer) for approximately 10 seconds. As this water is drawn into the separator, a measured amount of pretreatment chemical is mixed with the water. The separator uses a rotating bowl to separate urine and flush water from cabin gas. The bowl rotates at the speed required for a stationary impact tube to pump the liquid against a 5 psi back pressure into the waste collection tank. The separator air is driven through a bacteria filter and a charcoal filter for odor and bacteria removal and discharged into the cabin. The pretreated urine and flush water are transferred from the liquid/gas separator to a bladder operated waste collection tank. The crewman can urinate if no flush water is available since the urine will be mixed with pretreatment chemical and transferred for processing.

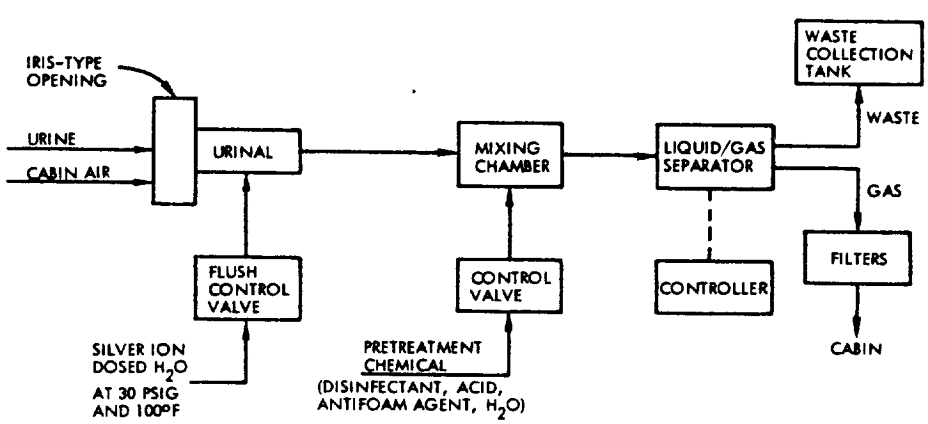


Figure 3-17. Urine Collection Module

*Data extracted from Reference 2

Urine Collection Module Engineering Data

Fixed Weight (FW in lb)

Urinal	0.6N
Mixing chamber	0.5N
Controller	6.0N
Fan and pump	8.0N
Electrical valves	3.9N
Manual valve	1.4N
Total FW =	20.4N

Fixed Volume (FV in ft^3)

Urinal	0.18N
Mixing chamber	0.03N
Controller	0.60N
Fan and pump	0.65N
Electrical valves	0.04N
Manual valve	0.01N
Total FV =	1.51N

Pretreatment Chemical usage rate (PC_R - composed of disinfectant, acid, antifoam agent and water)

PC_R = 1.2 lb per lb of urine

Water Influx from WMS (WI in lb/day)

WI - (2.0 lb/man-day)C

WI = 2.0C

Processing Rate, average (PR in lb/hr)

PR = 3.0N

Spares Weight (SW in lb)

Urinal	0.6N
Mixing chamber	0.3N
Controller	6.0N
Fan and pump	8.0N
Electrical valve	0.9N
Manual valve	0.8N
Total SW =	16.6N

Spares Volume (SV in ft^3)

Urinal	0.06N
Mixing chamber	0.01N
Controller	0.40N
Fan and pump	0.28N
Electrical valve	0.01N
Manual valve	0.01N
Total SV =	0.77N

3.2 FECES COLLECTION AND PROCESSING

3.2.1 Requirements.

- The capacity to collect feces from defecations shall be as follows:

amount:	wet weight; 0.66 lb/use maximum, 0.33 nominal dry weight; 0.275 lb/use maximum, 0.08 nominal
frequency:	0 to 2 times per man-day, 1 nominal
characteristics:	H_2O content; 65 to 90%, 75% nominal pH; 6.9 to 7.7 specific gravity; 1.0 to 1.4, 1.2 nominal
constituents:	water, electrolytes, nitrogen compounds, organic compounds, vitamins, amino acids

- Provisions shall be incorporated to provide for diarrhetic defecation collection.
- Microbial and chemical activity shall be permanently eliminated except in the case of biological treatment processes.
- Fecal wastes shall be treated as soon as possible after each defecation.
- The capacity to process feces shall be as follows:

amount:	wet weight; 0.66 lb/use maximum, 0.33 lb/use nominal dry weight; 0.275 lb/use maximum, 0.08 lb/use nominal
frequency:	0 to 2 times per man-day, 1 nominal
quality:	pH; 6.9 to 7.7 specific gravity; 1.0 to 1.4, 1.2 nominal
dry constituents:	organic and inorganic chemicals, bacteria

- Feces should be treated to prepare the waste output for final disposition.
- The collection process shall not expose personnel to the space environment.
- Sensory (visual, olfactory, and tactile) isolation from collected feces shall be provided.
- The fecal smear shall be removed from the anal area after each defecation. The cleansing agents should be non-irritating, non-toxic, non-volatile, non-explosive, non-flammable, and shall be evaluated as to effect on microbial flora, but shall allow an adequate level of sebum to be maintained.

3.2.2 Concept Descriptions and Engineering Data. The feces collection and processing concepts discussed in this section are: a) The Chemical Toilet System, b) the Dry John System, c) the Automated Bag System, d) the Hydro-John and e) the Fecal Collection Module.

Chemical Toilet System (Figure 3-18)

This system combines the following concepts:

- Stationary toilet seat formed to the lower buttocks, using air transport of feces to a slinger/separator.
- Deactivation of feces by chemical treatment, with return of waste to earth by shuttle.

Cabin air entering from inlet ports located just under the seat creates viscous drag forces on the feces, transporting it to a motor-driven slinger/separator. At this point, the feces are separated from the air stream. Air passes out of the unit through a coarse filter which removes large particulates and aerosols. The slinger/separator breaks up the solid fecal mass into multiple small pieces which are slung against the container wall where a thin coating of feces is created. Liquid germicide is sprayed onto this layer, where it permeates the feces and deactivates all microbial growth.

The oval container with the slinger/separator is a replaceable item, considered an expendable. Each unit is sized to hold 400 man-days of feces. The motor drive unit and the seat unit are changed from the full to the empty container much as a kitchen blender is used. A container storage rack is provided for either empty or full containers.

Air flow for feces transport and odor control (common to all systems) is provided by a process fan. Odor control is accomplished by passing the transport air through an odor control cartridge which utilizes lead dioxide for hydrogen sulfide removal and activated charcoal for ammonia and hydrocarbon removal. Each cartridge is sized to last for 600 man-days of use. The expendable cartridges fit into a fixed canister which is a part of the air transport package. A bacteria filter is provided upstream of the odor control canister to remove bacteria and other fine particulates from the process flow.

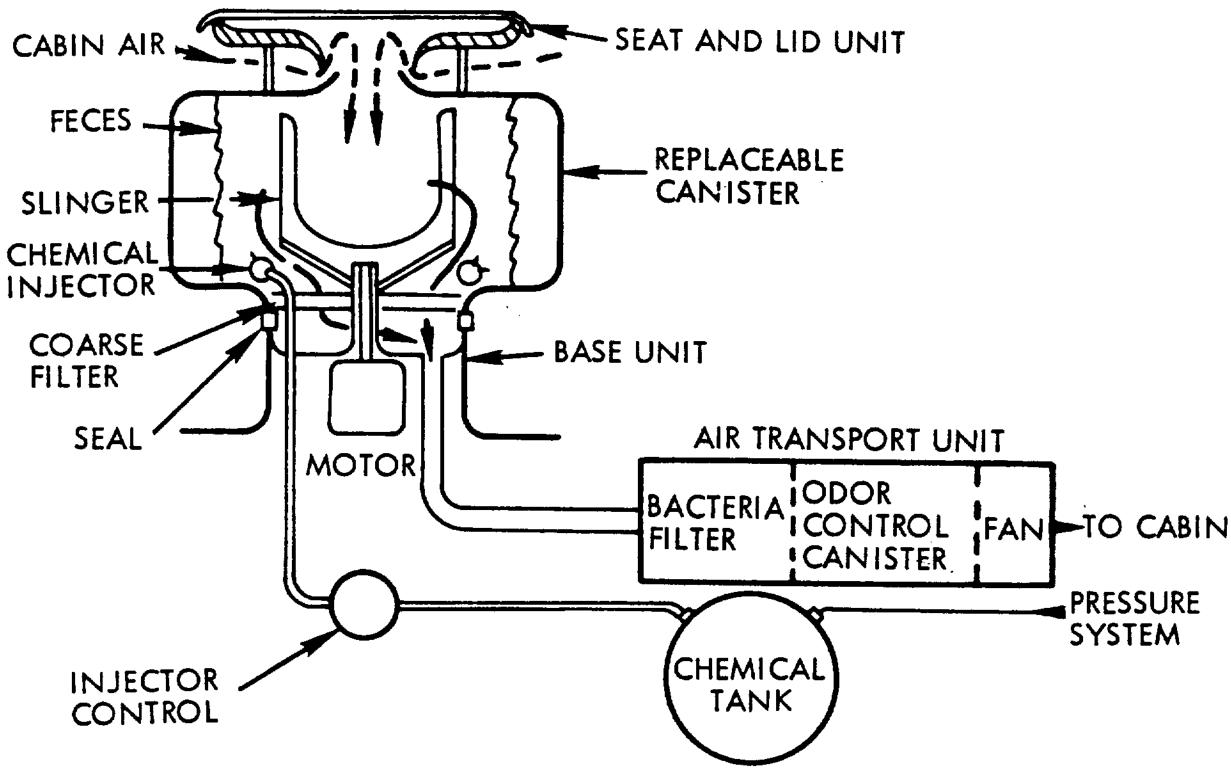


Figure 3-18. Chemical Toilet System

Chemical Toilet System Engineering Data

Fixed Weight (FW in lb)			Figure 3-19
Storage rack		0.0055CR	
Seat and lid		1.8N	
Air transport			
Fan	5.0N		
Canister	1.0N		
Filter housing	3.5N		
Structure	2.6N		
Ducting	$3.8N/P^{0.25}$		
(See Appendix A)		$(12.1+3.8/P^{0.25})N$	
Base unit		4.5N	
Chemical system			
Tank	0.00083CR		
Injector	7.0N		
		7.0N+0.00083CR	
	Total FW =	$(25.4+3.8/P^{0.25})N+0.00633CR$	

Fixed Volume (FV in ft^3)		Figure 3-20
Storage rack	0.0125CR	
Air transport	2.25N	
Collector unit	8.0N	
Chemical tank	0.00055CR	
Chemical injector	0.25N	
Total FV =	10.5N+0.01305CR	

Expendable Weight (EW in lb/day)		
Containers	0.035C	
Odor cartridges	0.1C	
Filter elements	0.0033C	
Liquid germicide	0.00833C	
Total EW =	0.147C	
Expendable Volume (EV in ft^3/day)		
Containers	0.0125C	
Odor cartridges	0.0025C	
Filter elements	0.000055C	
Liquid germicide	0.00055	
Total EV =	0.0156C	
Power Maximum (PM in watts)		Figure 3-21
Slinger	140.0	
Fan (See Appendix A)	$382.0/P^{0.5}$	
Total PM =	$140.0+382.0/P^{0.5}$	

Power, Average (PA in watt-hours/day) — Figure 3-22

PA = (use time/man-day)(PM)C

$PA = 0.1\ (140+382/P^{0.5})C$

$PA = (14.0+38.2/P^{0.5})C$

Cooling from atmosphere, peak (Q_{CP} in Btu/minute) — Figure 3-23

$Q_{CP} = 0.034\ PM_F$ (See Appendix A)

$Q_{CP} = 13.0/P^{0.5}$

Cooling from atmosphere, average (Q_{CA} in Btu/day) — Figure 3-24

Q_{CA} = (use time/man-day)(Q_{CP})C

$Q_{CA} = 6(13.0/P^{0.5})C$

$Q_{CA} = 78.0C/P^{0.5}$

Water Vapor rejected to atmosphere (WV in lb/day)

Fecal rate $(T_1-T_2)C_pC = (WV)h_{fg}$

if C_p = 1.22 Btu/lb/°F

0.33(97-70)1.22C = 1100 WV

WV = 0.01C

Initial and resupply period spares weight (SI and SR in lb) — Figures 3-25 and 3-26

See Appendix A for equations and variables.

$$FW = (25.4 + 3.8/P^{0.25})N + 0.00633CR$$

$$FW = \text{Factor A} + \text{Factor B}$$

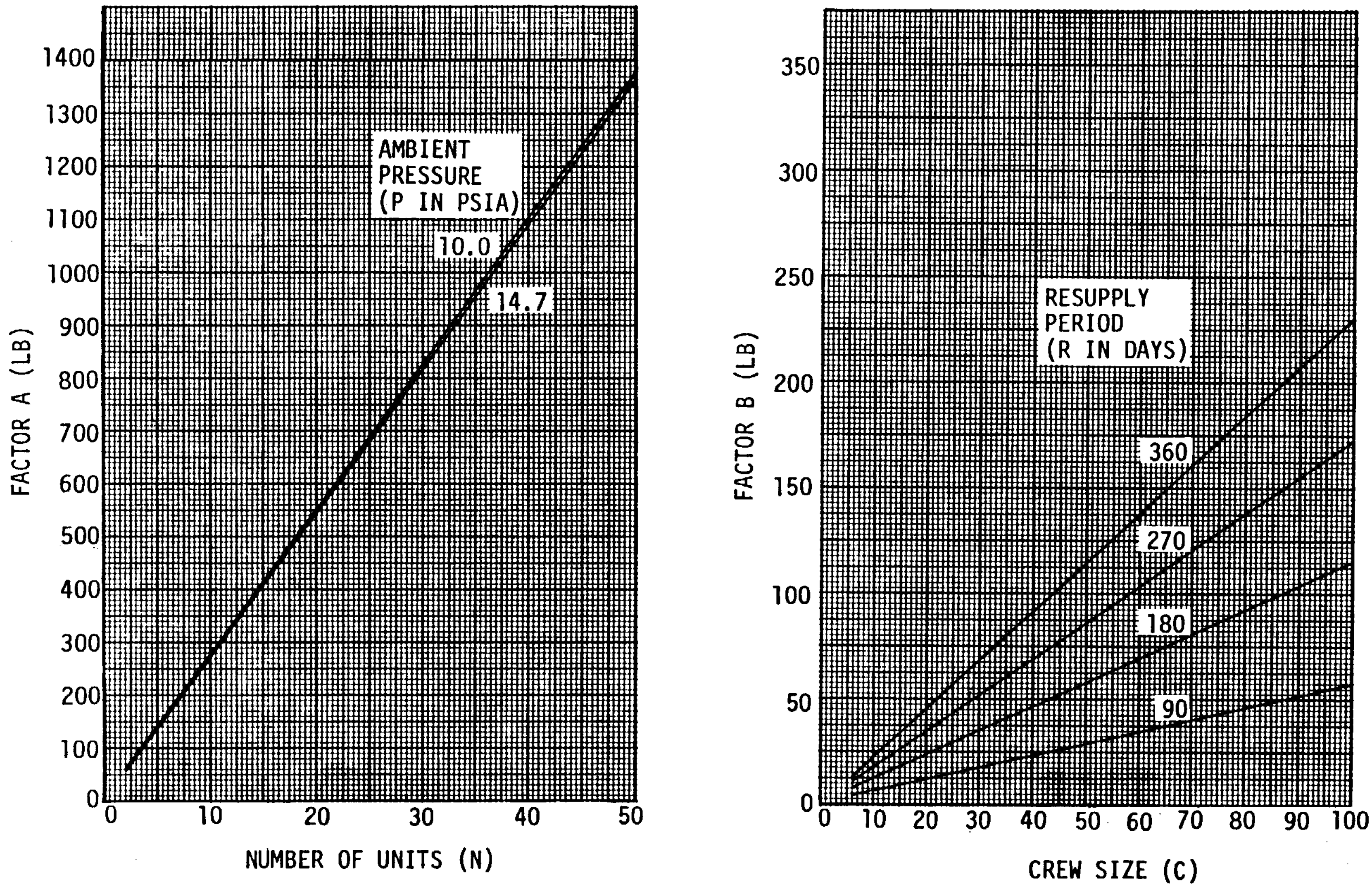
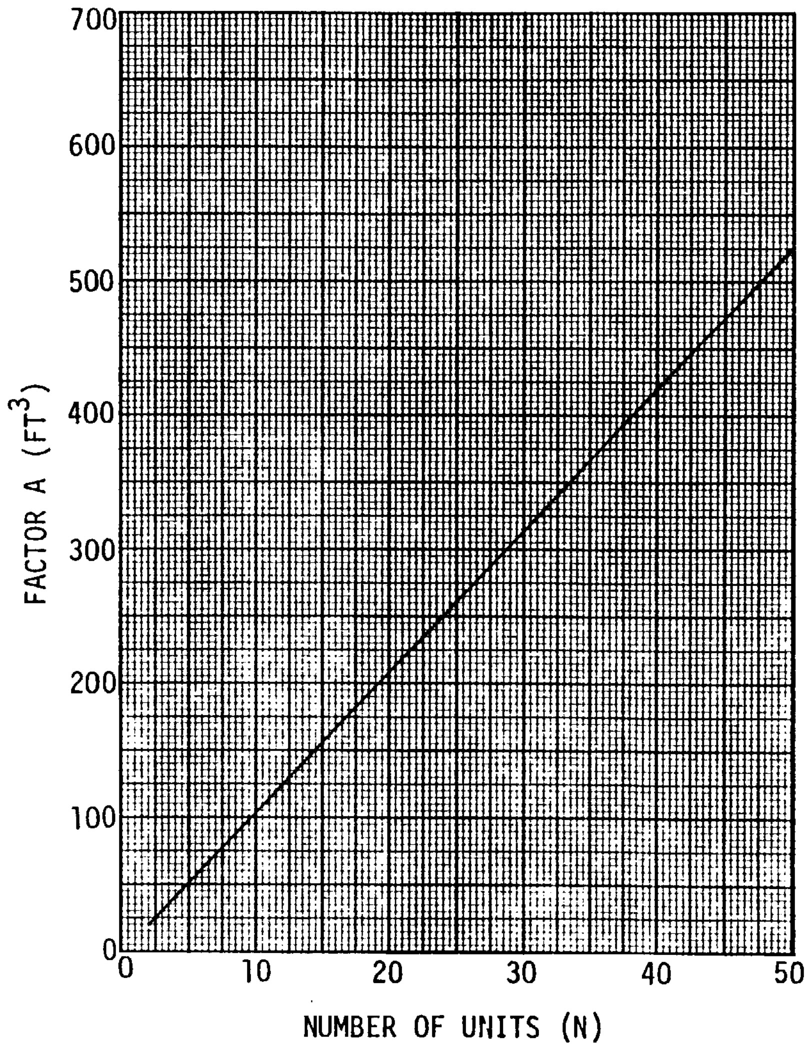


Figure 3-19. Chemical Toilet System Fixed Weight

$FV = 10.5N + 0.01305CR$

$FV = \text{FACTOR A} + \text{FACTOR B}$



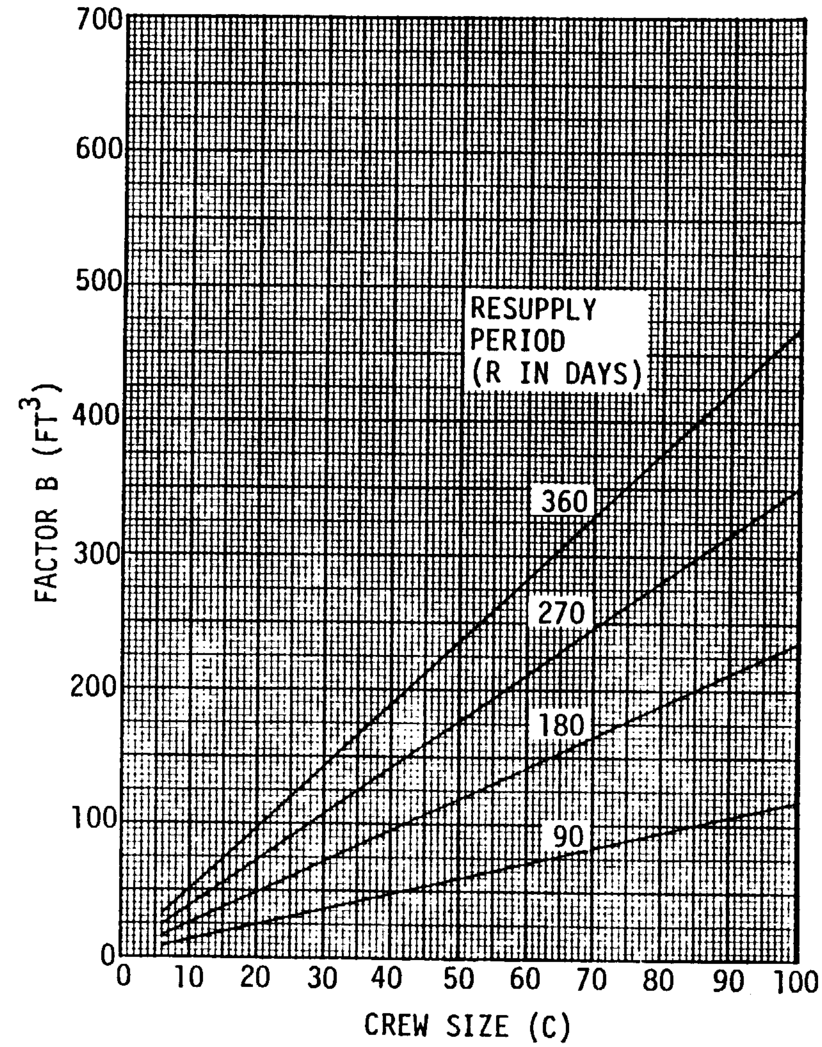


Figure 3-20. Chemical Toilet System Fixed Volume

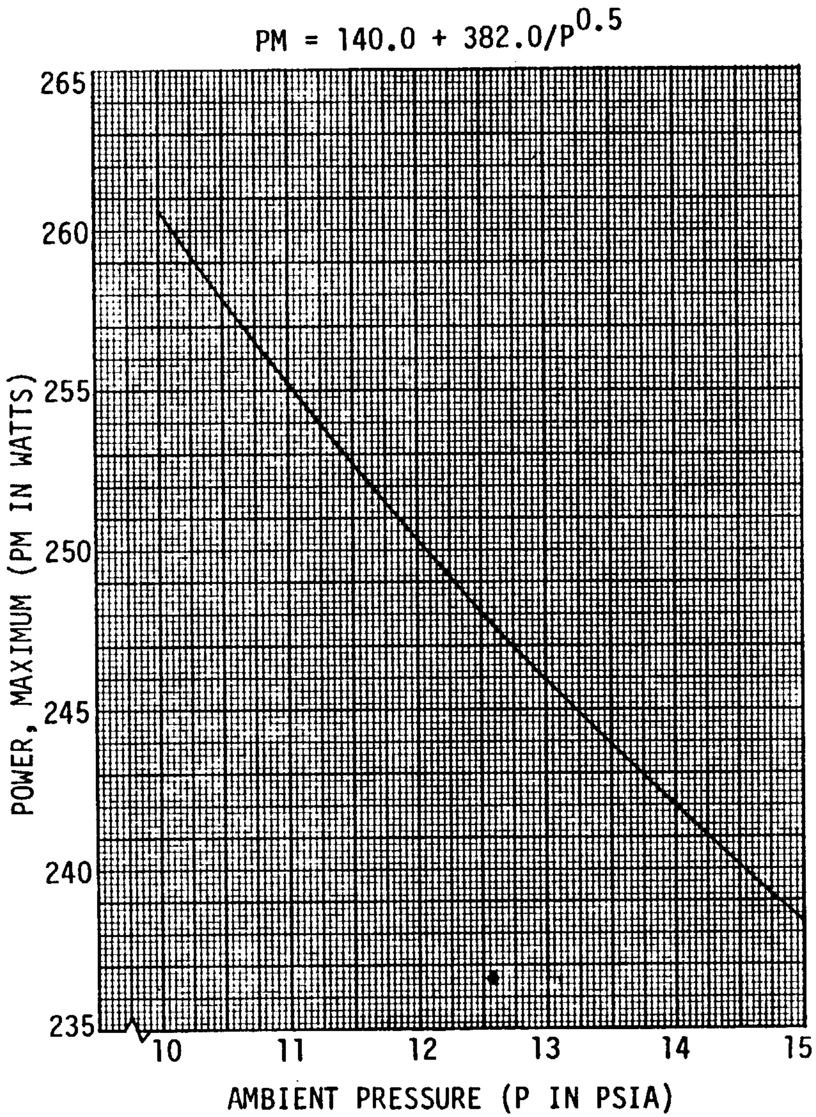


Figure 3-21. Chemical Toilet System Power, Maximum

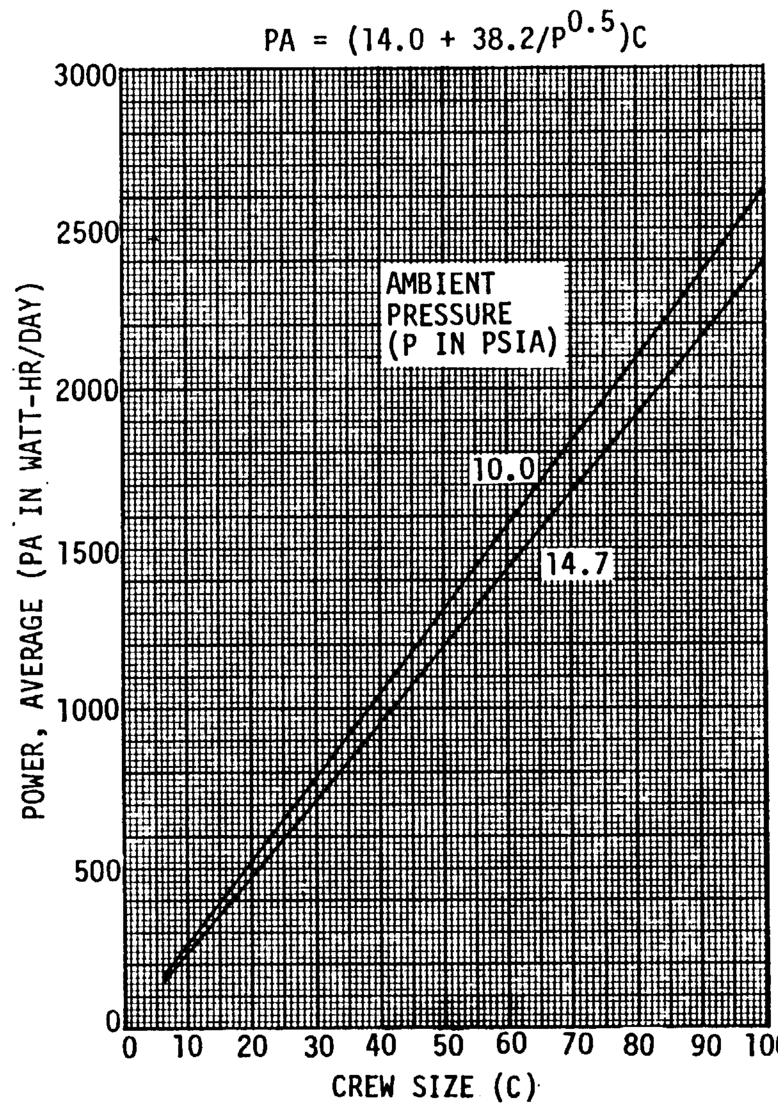


Figure 3-22. Chemical Toilet System Power, Average

$Q_{CP} = 13.0/P^{0.5}$

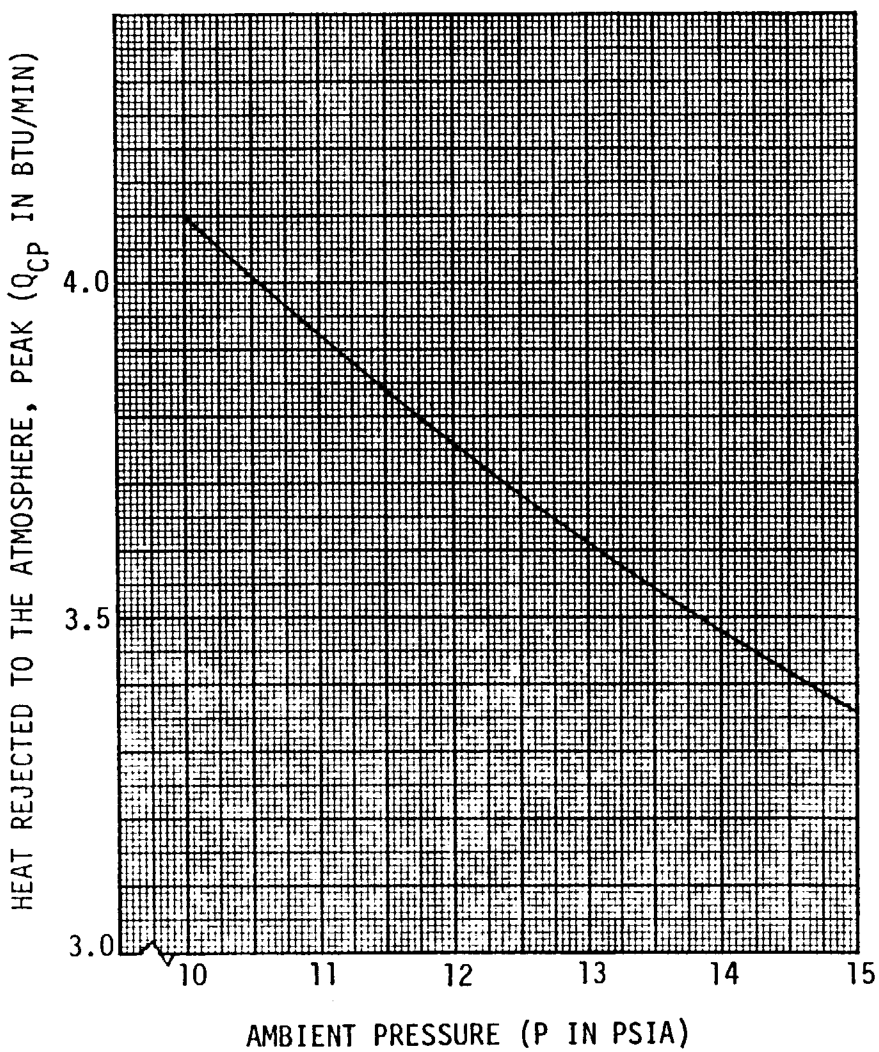


Figure 3-23. Chemical Toilet System Heat Rejected to the Atmosphere, Peak

$Q_{CA} = (78.0C/P^{0.5})$

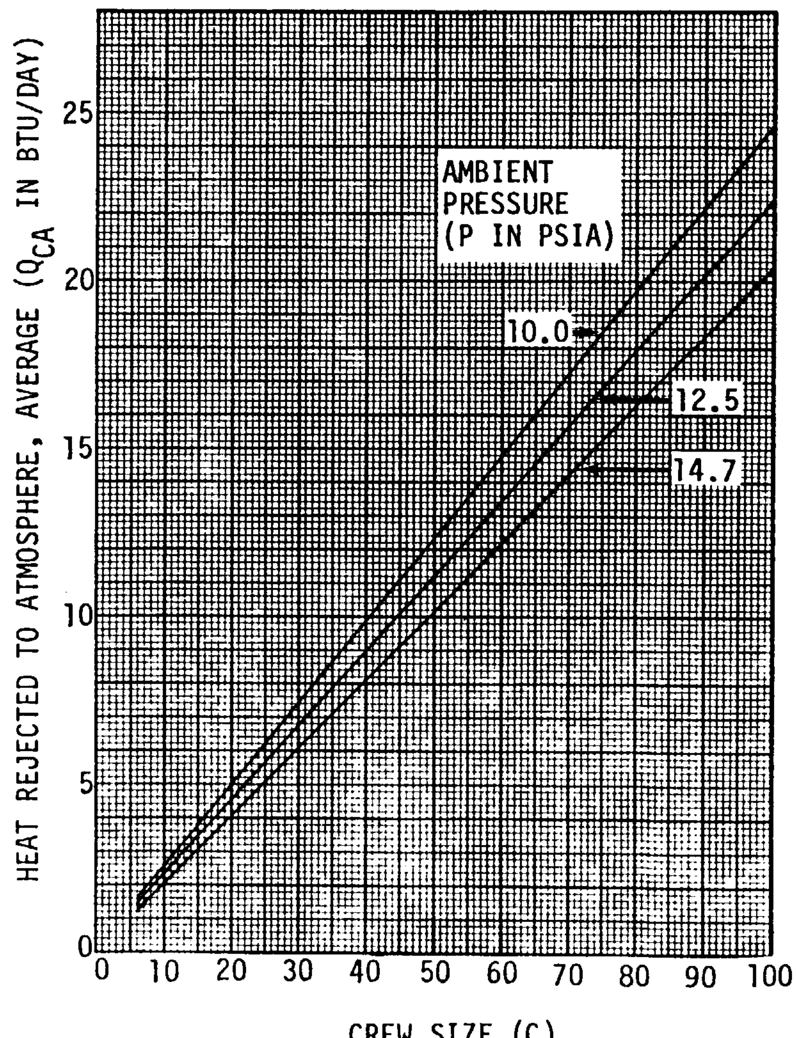


Figure 3-24. Chemical Toilet System Heat Rejected to the Atmosphere, Average

Equation Provided in Paragraph A.6.2 of Appendix A

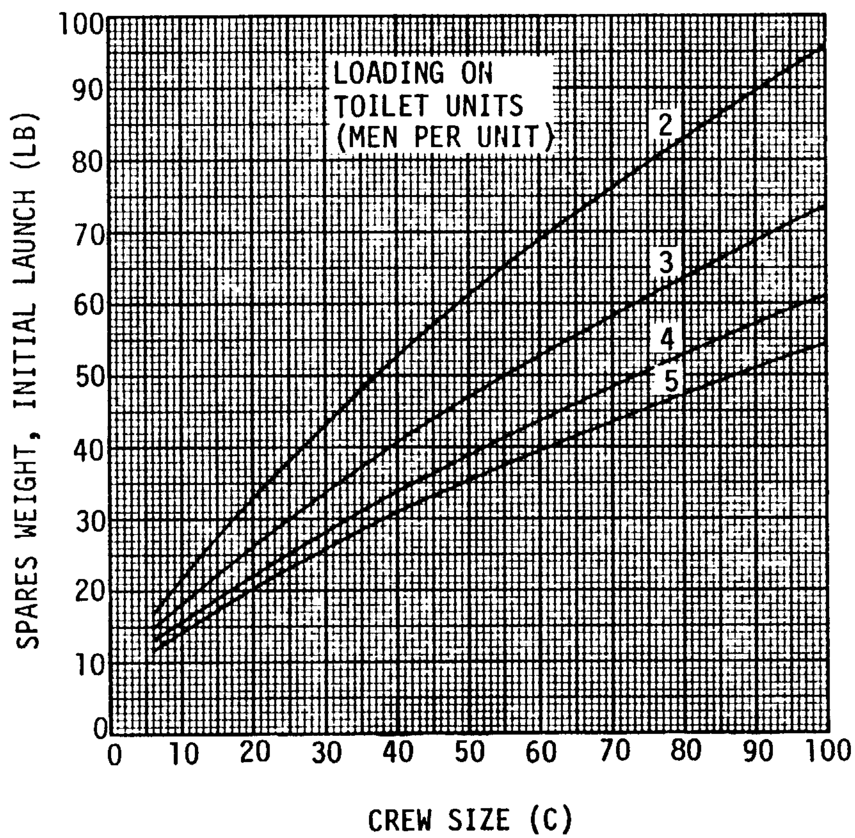


Figure 3-25. Chemical Toilet System Initial Spares Weight

Equation Provided in Paragraph A.6.3 of Appendix A

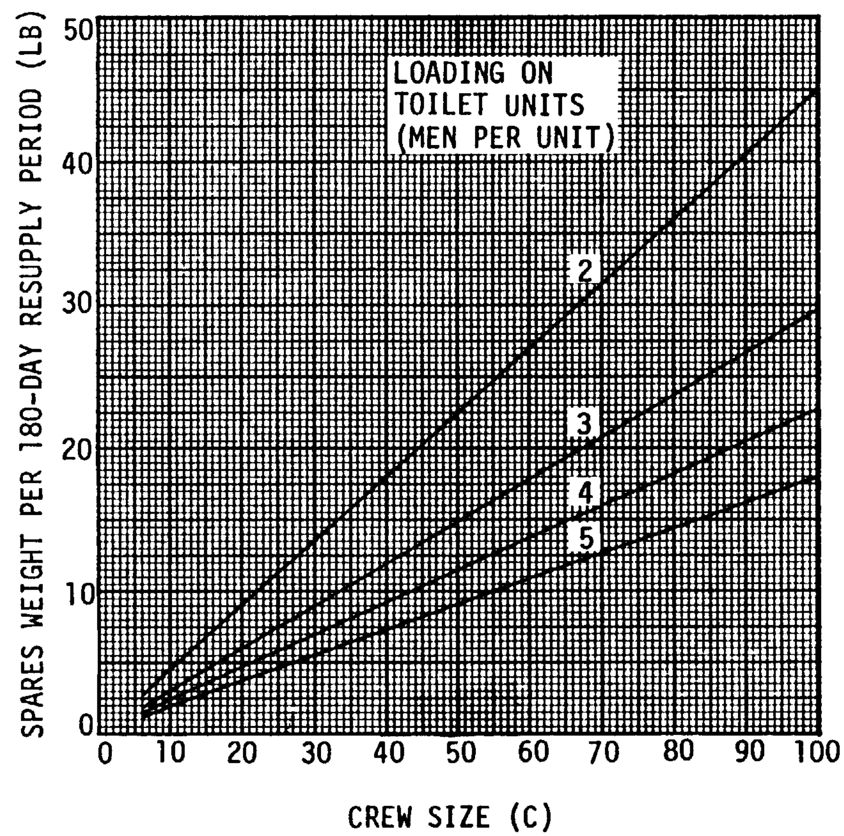


Figure 3-26. Chemical Toilet System Resupply Period Spares Weight

Dry John System (Figure 3-27)

This system combines the following concepts:

- Stationary toilet seat formed to the lower buttocks, using air transport of feces to a slinger/separator
- Deactivation of feces by dehydration with return of waste to earth by shuttle.

An air transport system, as described in the Chemical Toilet System, is used to transport the feces from the anus to a slinger/separator. The slinger/separator breaks up the solid fecal mass into multiple small pieces which are slung against the container wall forming a thin layer with a large surface area. After defecation is completed, the lid is closed and the collection container is sealed at the inlet with a gate valve. A vacuum pump is activated to reduce the pressure in the container to one psia. At this pressure, the pump system is deactivated and the vent valve is opened to outer space. The residual atmosphere in the container is lost and the pressure is reduced to near space vacuum. Dehydration of the feces occurs, deactivating microbial growth and reducing the volume and weight of feces. The vent valve is left open continuously between defecations. The oval container is a replaceable unit. Each unit is sized to hold 600 man-days of feces.

Dry John System Engineering Data

Fixed Weight (FW in lb)		Figure 3-28
Storage rack	0.0033CR	
Seat and lid	1.8N	
Air transport (See Chemical Toilet System data)	$(12.1+3.8/P^{0.25})N$	
Base unit	4.5N	
Pump and vent unit	4.0N	
Total FW =	$(22.4+3.8/P^{0.25})N+0.0033CR$	

Fixed Volume (FV in ft^3)		Figure 3-29
Storage rack	0.00667CR	
Air transport unit	2.25N	
Collector unit	6.0N	
Pump and vent unit	0.75N	
Total FV =	9.0N+0.00667CR	

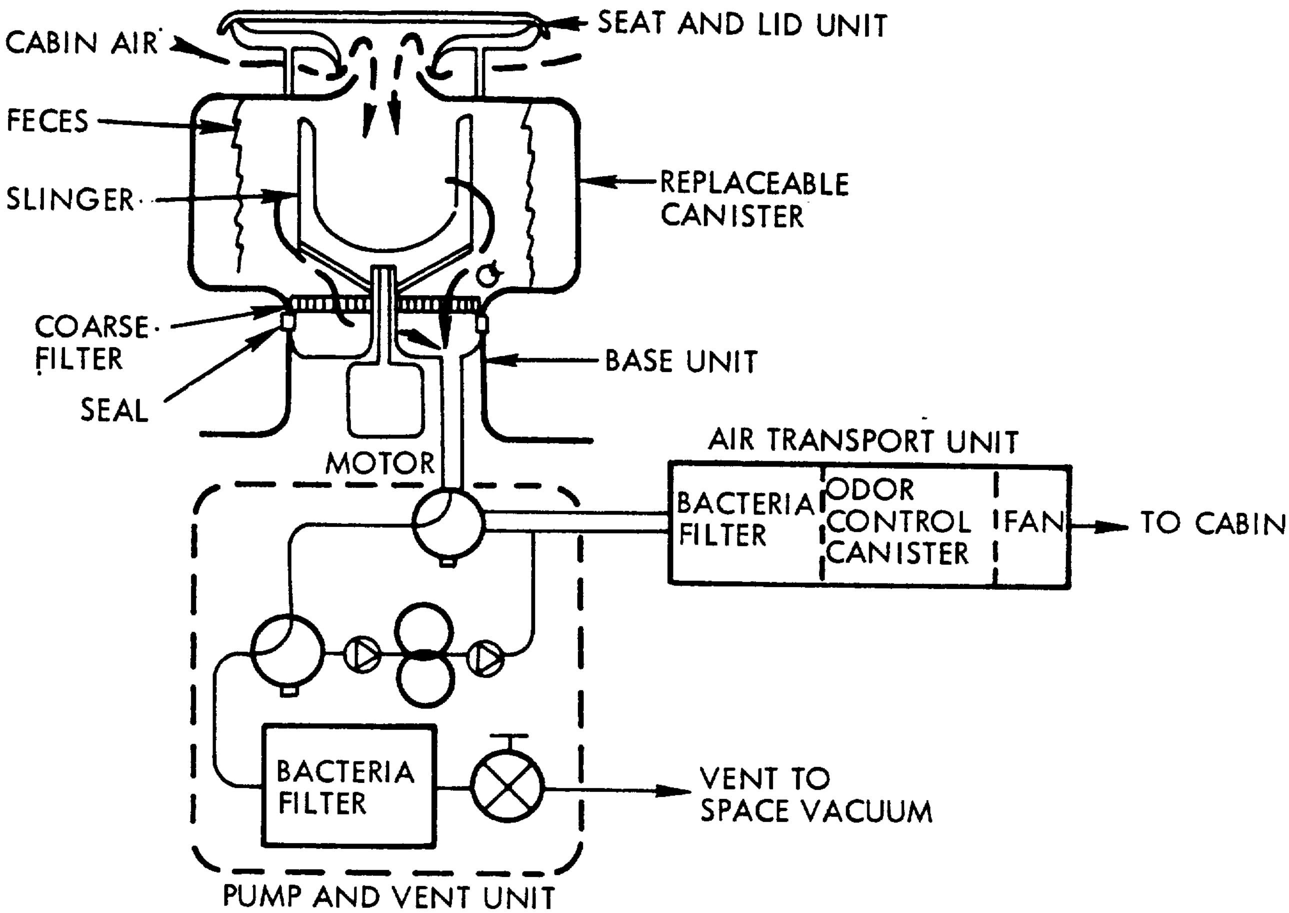


Figure 3-27. Dry John System

Weight of Atmosphere Lost (AL in lb) — Figure 3-30

Venting loss		0.015C
Leakage loss=(leakage rate per unit length)(length)		
0.00278P(3N)		0.00834PN
	Total AL =	0.015C+0.00834PN

Expendable Weight (EW in lb/day) — Figure 3-31

Containers		(0.015+0.00056P)C
Odor cartridges		0.1C
Filter elements		0.0033C
	TOTAL EW =	(0.1183+0.00056P)C

Expendable Volume (EV in ft^3/day)

Containers		0.00667C
Odor cartridges		0.0025C
Filter elements		0.000055C
	Total EV =	0.0092C

Power, Maximum (PM in Watts) — Figure 3-32

Slinger		100.0
Pump		30.0
Fan (See Appendix A)		$382.0/P^{0.5}$
$PM^* = PM_S + PM_F$	Total PM =	$100.0+382.0/P^{0.5}$

*Pump is not on when fan and slinger operate.

Power, Average (PA in watt-hours/day) — Figure 3-33

PA_X = Use time per man-day = $(PM_X)C$

Slinger	0.1 (100.0)C =	10.0C
Pump	0.05(30.0)C =	1.5C
Fan	$0.1\ (382.0/P^{0.5})C$ =	$38.2C/P^{0.5}$
	Total PA =	$(11.5+38.2/P^{0.5})C$

Cooling from atmosphere, Peak (Q_{CP} in Btu/minute) — Figure 3-34

$Q_{CP} = 0.034\ PM_F$ (See Appendix A)

$Q_{CP} = 0.034\ (382.0/P^{0.5})$

$Q_{CP} = 13.0/P^{0.5}$

Cooling from atmosphere, Average (Q_{CA} in Btu/day) — Figure 3-35

Q_{CA} = (use time/man-day)$(Q_{CP})C$

$Q_{CA} = 6(13.0/P^{0.5})C$

$Q_{CA} = 78.0C/P^{0.5}$

Water Vapor rejected to atmosphere (WV in lb/day)

Fecal rate $(T_1-T_2)C_pC = (WV)h_{fg}$

if C_p = 1.22Btu/lb/°F

0.33 (97-90) 1.22 = 1100 WV

WV = 0.01C

Heating required from atmosphere (Q_H in Btu/day)

Q_H = Heat of vaporization of fecal water

$Q_H = h_{fg}$ (mass of water evaporated/man-day)C

$Q_H = 1100.0(0.2)C$

$\underline{Q_H = 220.0C}$

Initial and resupply period spares weight (SI and SR in lb) — Figures 3-36 and 3-37

See Appendix A for equations and variables

$$FW = (22.4 + 3.8/P^{0.25})\ N + 0.0033CR$$

$$FW = \text{Factor A} + \text{Factor B}$$

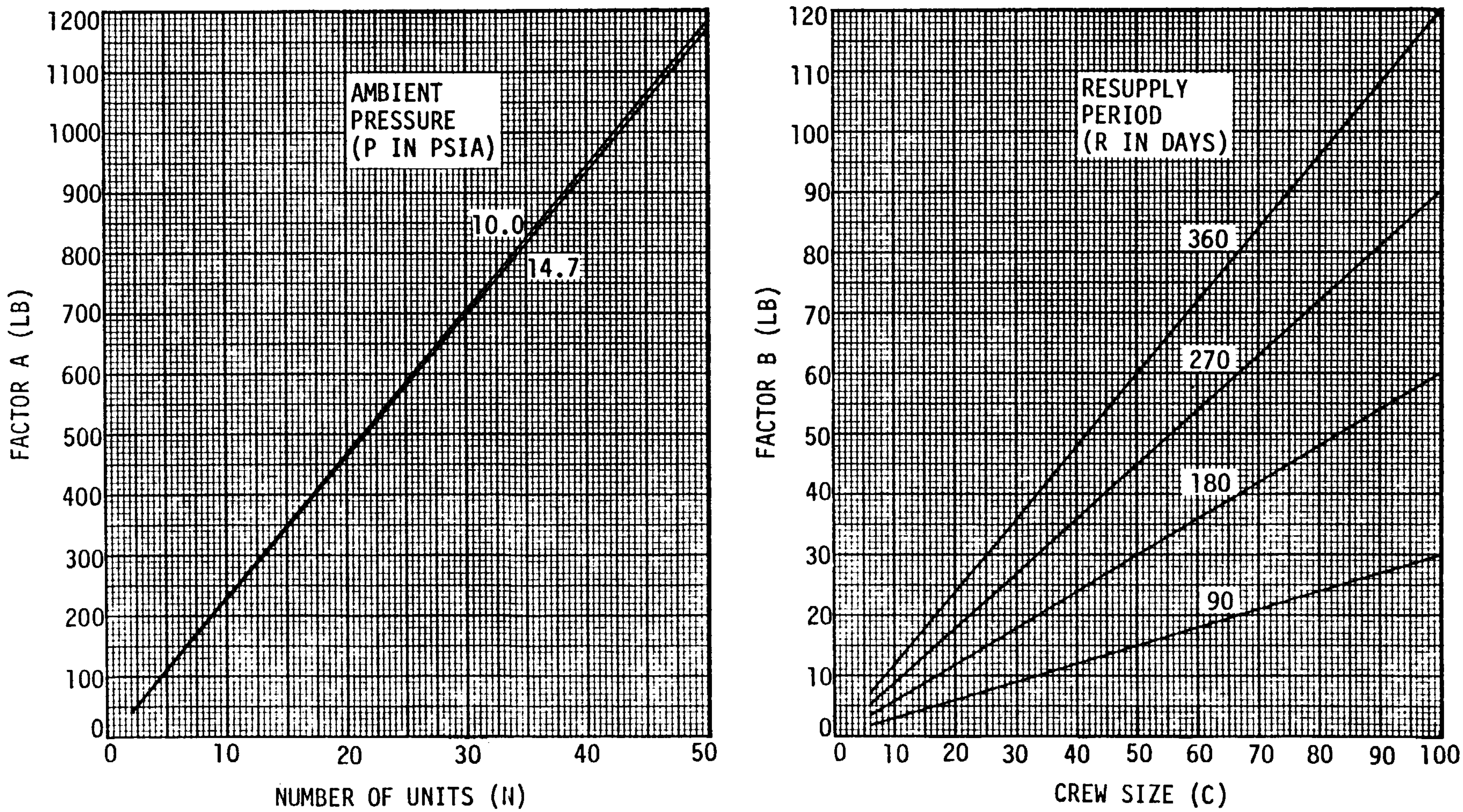


Figure 3-28. Dry John System Fixed Weight

$$FV = 9.0N + 0.00667\ CR$$

$$FV = \text{Factor A} + \text{Factor B}$$

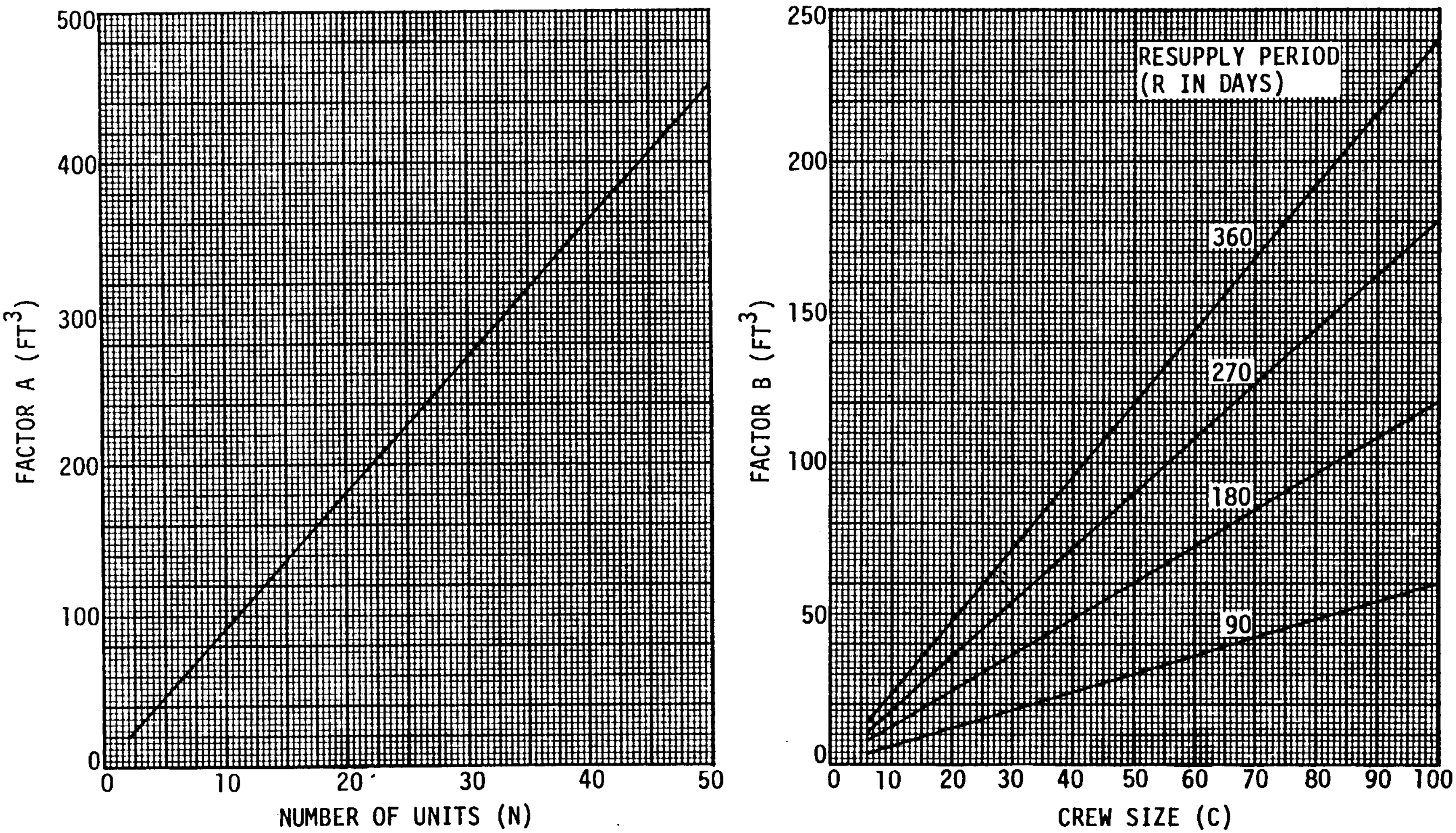


Figure 3-29. Dry John System Fixed Volume

$$AL = 0.015C + 0.00834PN$$
$$AL = \text{Factor A} + \text{Factor B}$$

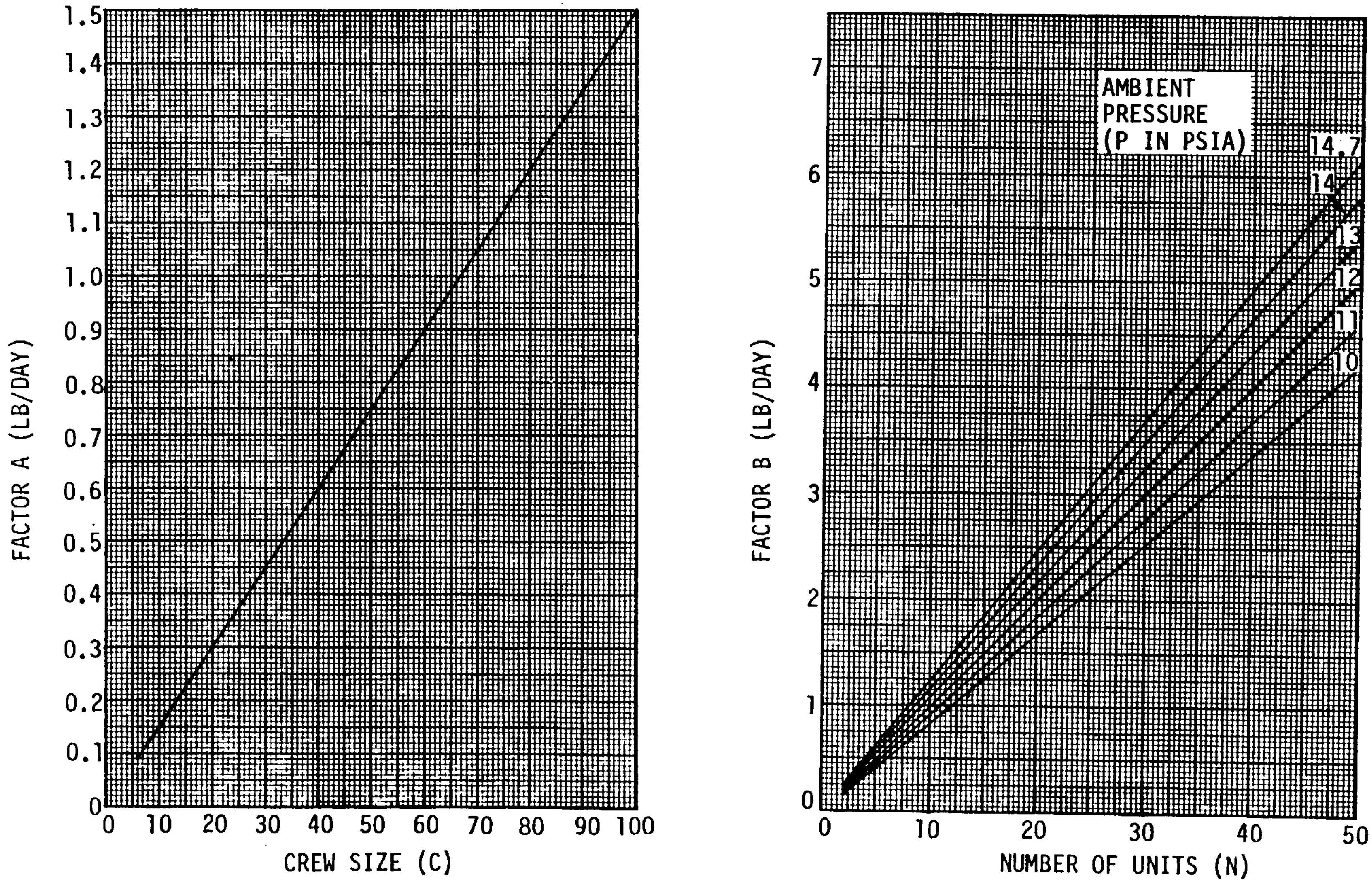


Figure 3-30. Dry John System Atmosphere Lost

$$EW = (0.1183 + 0.00056P)C$$

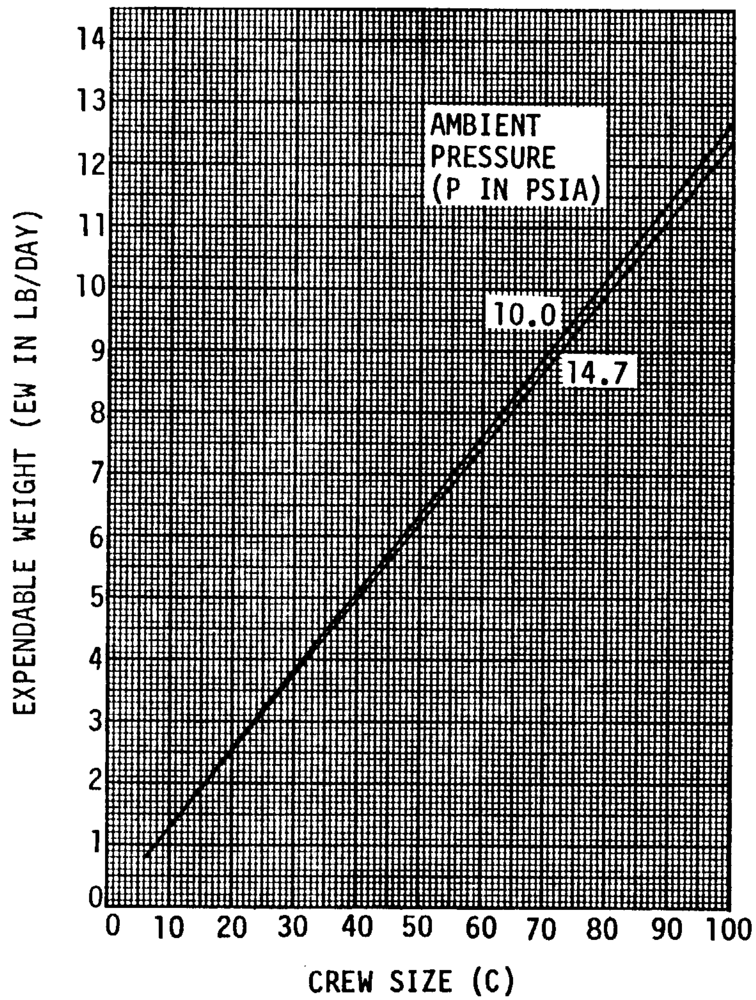


Figure 3-31. Dry John System Expendable Weight

$$PM = 100.0 + 382.0/P^{0.5}$$

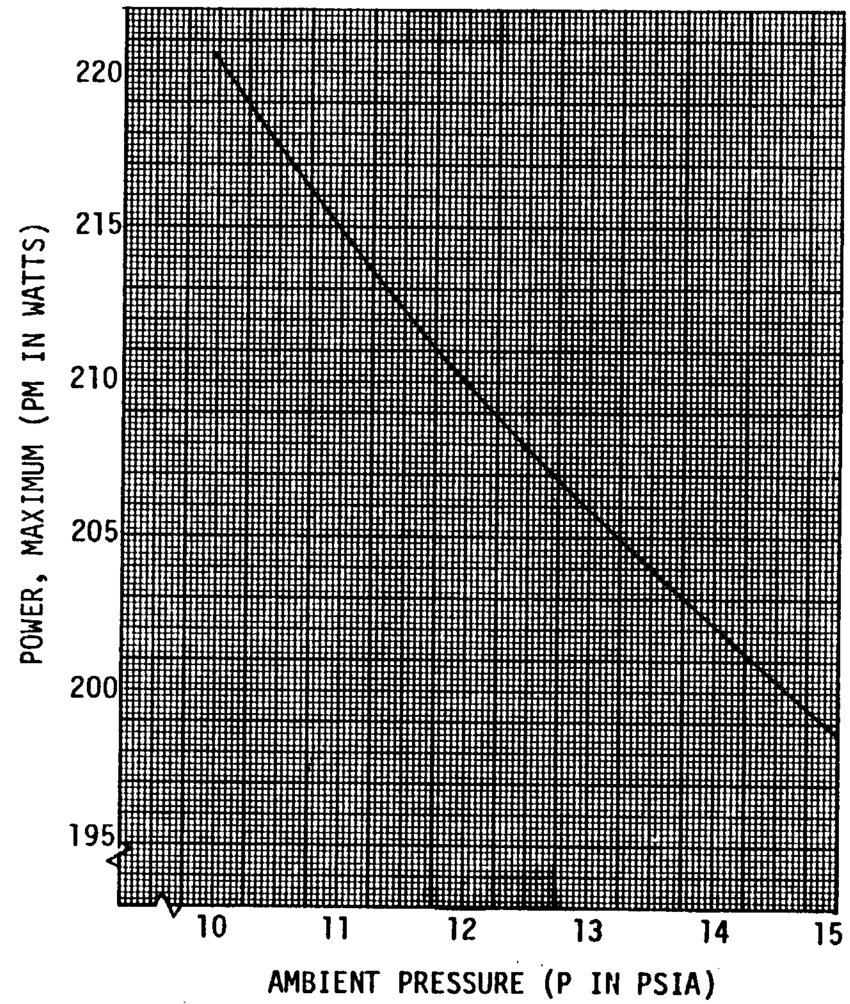


Figure 3-32. Dry John System Power, Maximum

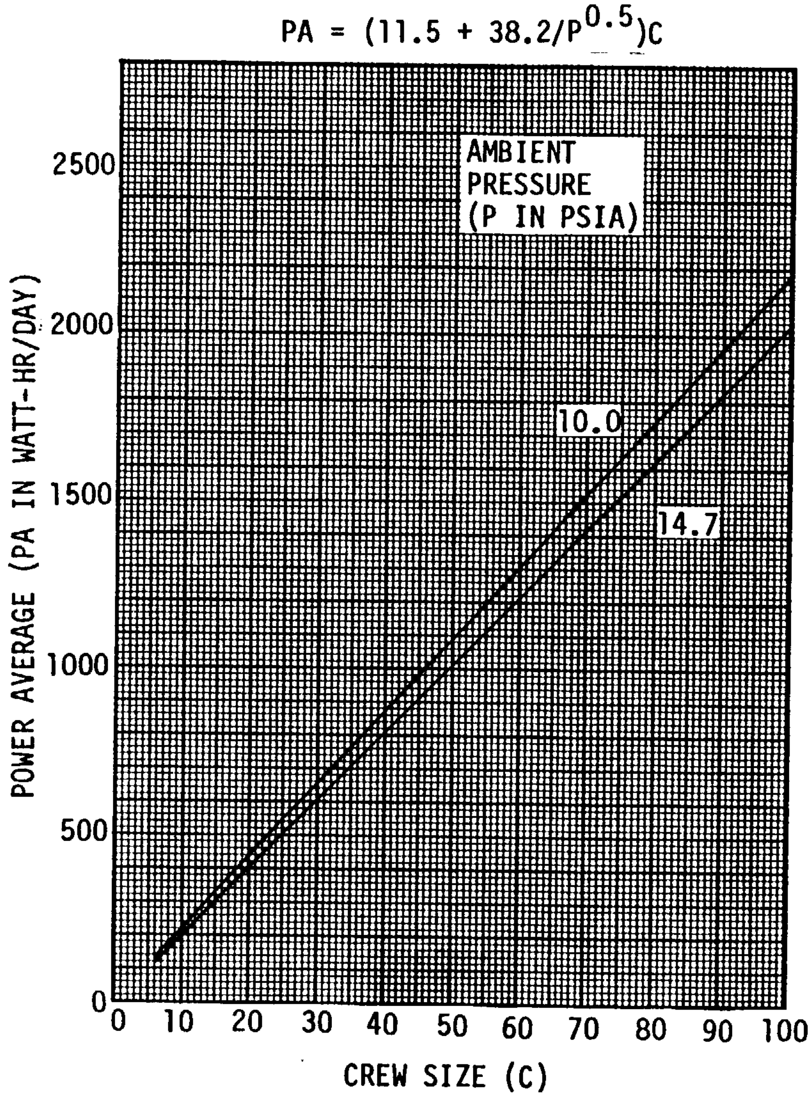


Figure 3-33. Dry John System Power, Average

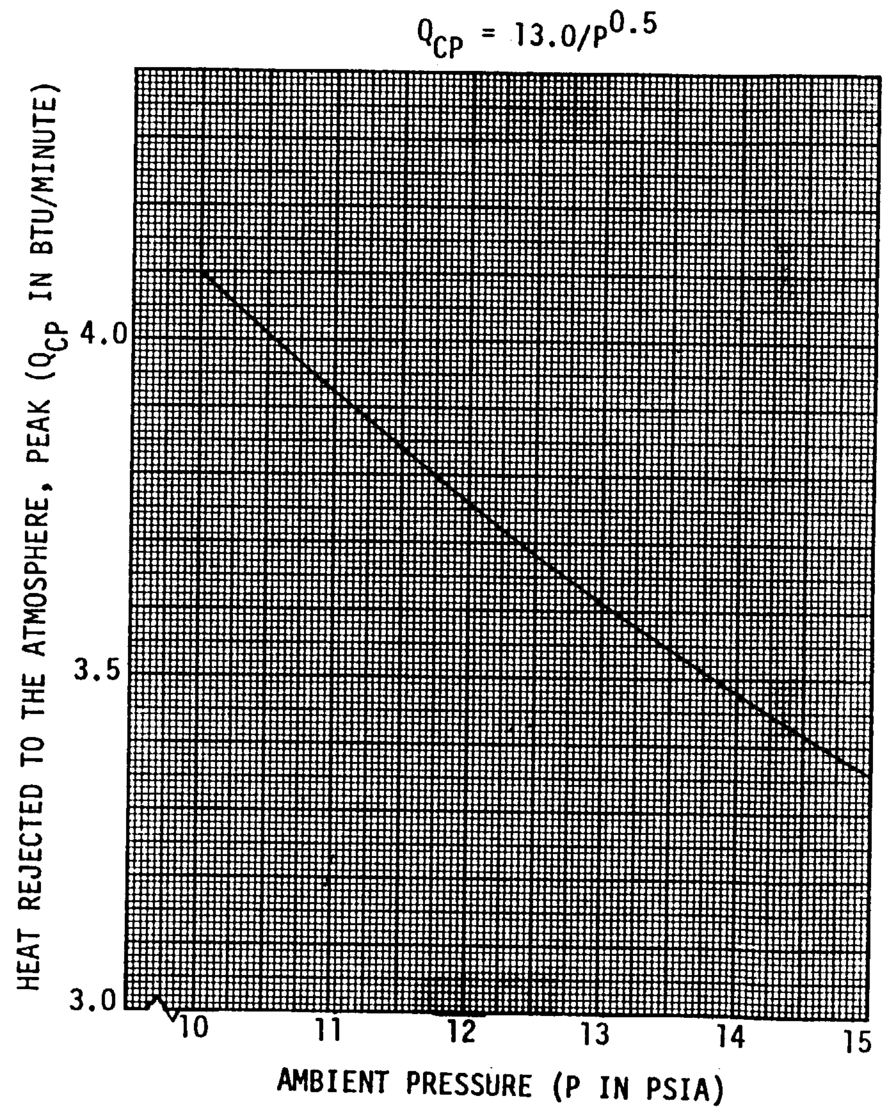


Figure 3-34. Dry John System Heat Rejected to the Atmosphere, Peak

$Q_{CA} = (78.0C/P^{0.5})$

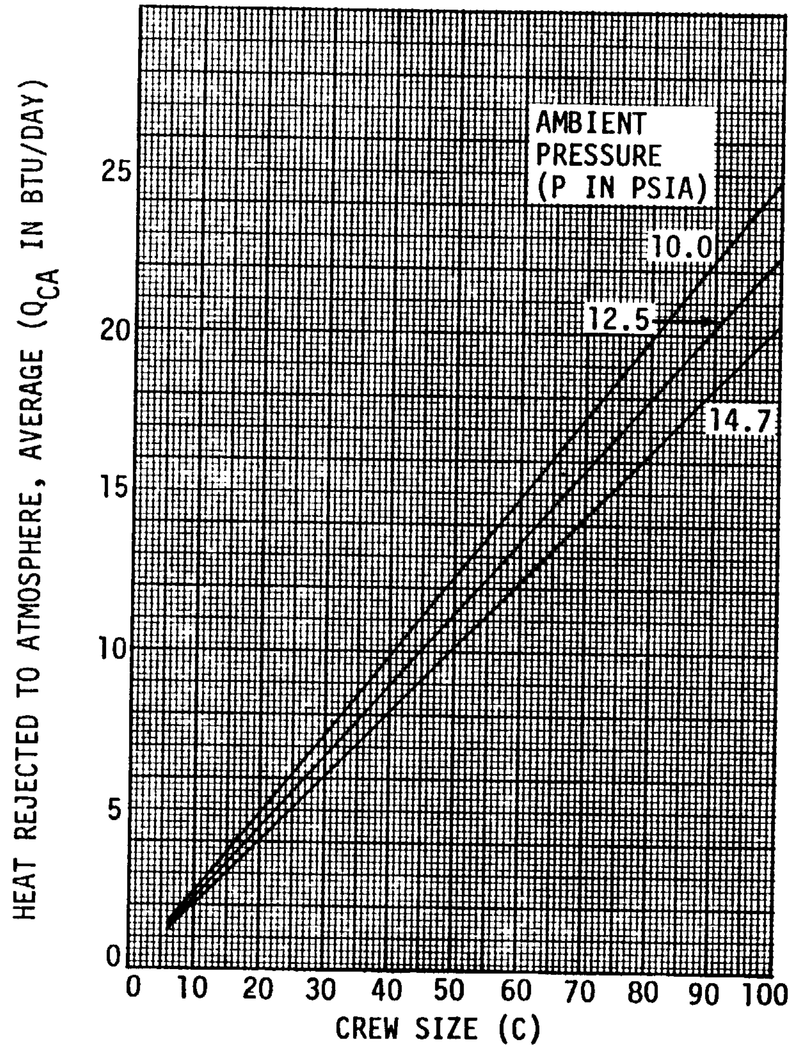


Figure 3-35. Dry John System Heat Rejected to the Atmosphere, Average

Equation Provided in Paragraph A.6.2 of Appendix A

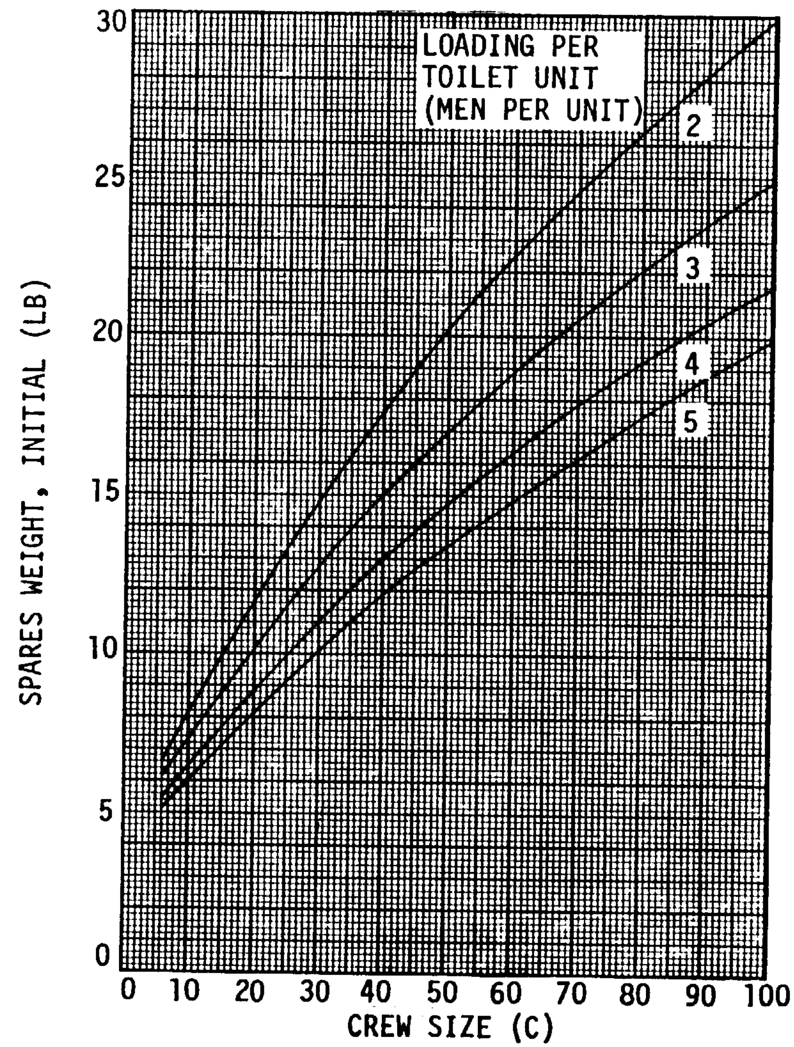


Figure 3-36. Dry John System Initial Spares Weight

Equation Provided in Paragraph A.6.3 of Appendix A

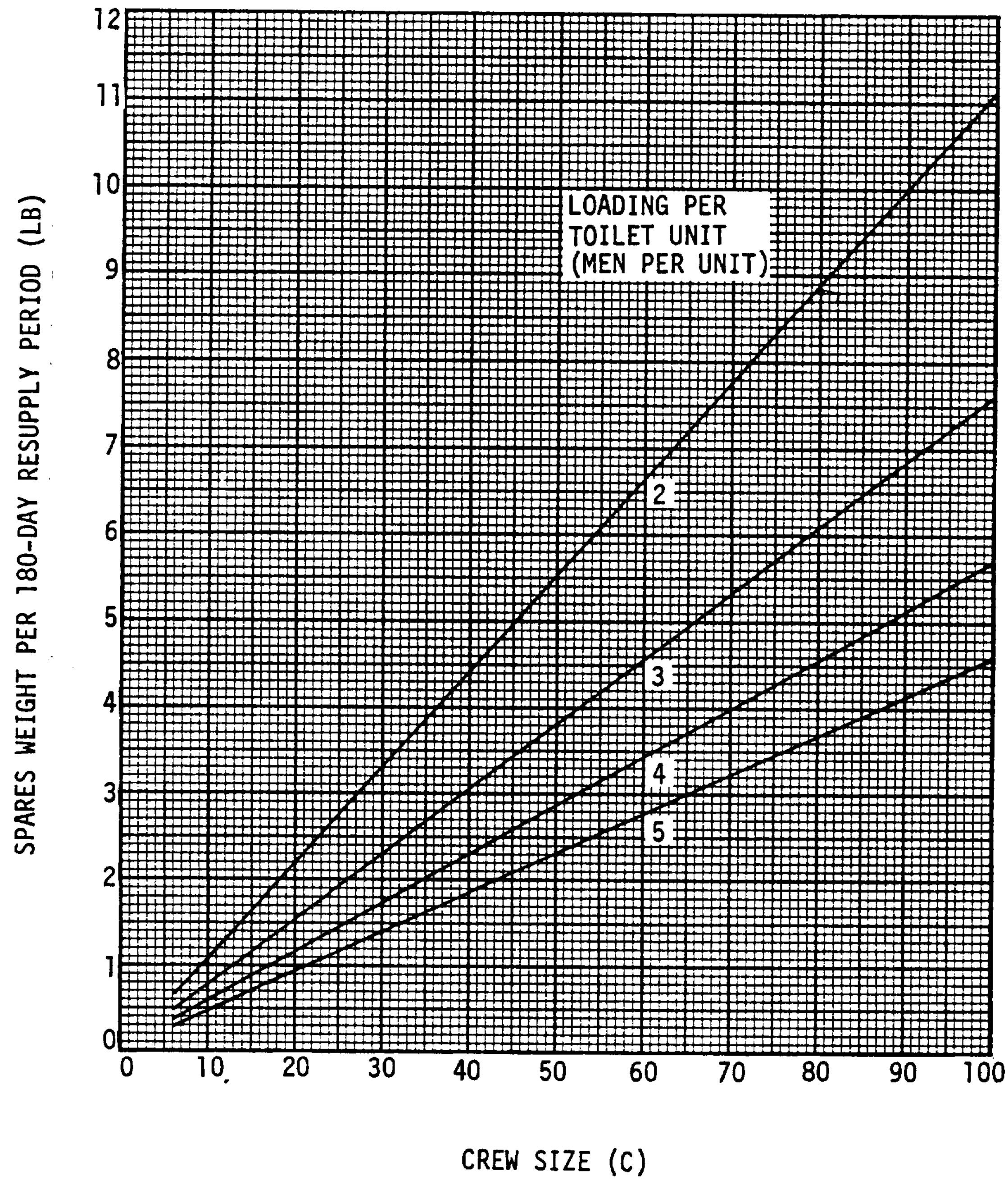


Figure 3-37. Dry John System Resupply Period Spares Weight

Automated Bag System (Figure 3-38)

This system combines the following concepts:

- Stationary toilet seat formed to the lower buttocks, using air transport of feces into a collection bag followed by automated transfer of the bag to the processor.
- Deactivation of feces by dehydration, with return of waste to earth by shuttle.

An air transport system, as described in the chemical toilet system, is used to transport the feces from the anus into a collection bag. The bag has a hydrophobic patch which allows passage of transport air but not the feces. After defecation is completed, the user operates a device which detaches and seals the top part of the bag from the seat. The bag is then pneumatically transported to a processing tank. The next user manually attaches a new bag to the seat, starts the blower, and the cycle is repeated.

The processor is connected to the collection unit by large diameter tubing and a gate valve which is opened to effect pneumatic transfer of the bag. After the bag is in the processor, a vacuum pump is used to reduce the pressure in the processor to one psia. The vent valve is then opened, reducing the pressure to space vacuum. Dehydration of the feces occurs, deactivating microbial growth and reducing the weight and volume of feces. The vent valve is left open continuously between defecations. A small heater in the processor is used to supply heat to dry the feces, since the surface area of the feces contacting the container wall is small compared to the slinger system.

The processor tank is sized to hold 600 man-days of feces and bags. When full, the processor tank is opened, and the feces are removed in a plastic liner shell provided for that purpose. The tank is closed after a new liner shell has been installed. The dried feces are stored for the duration of the resupply period.

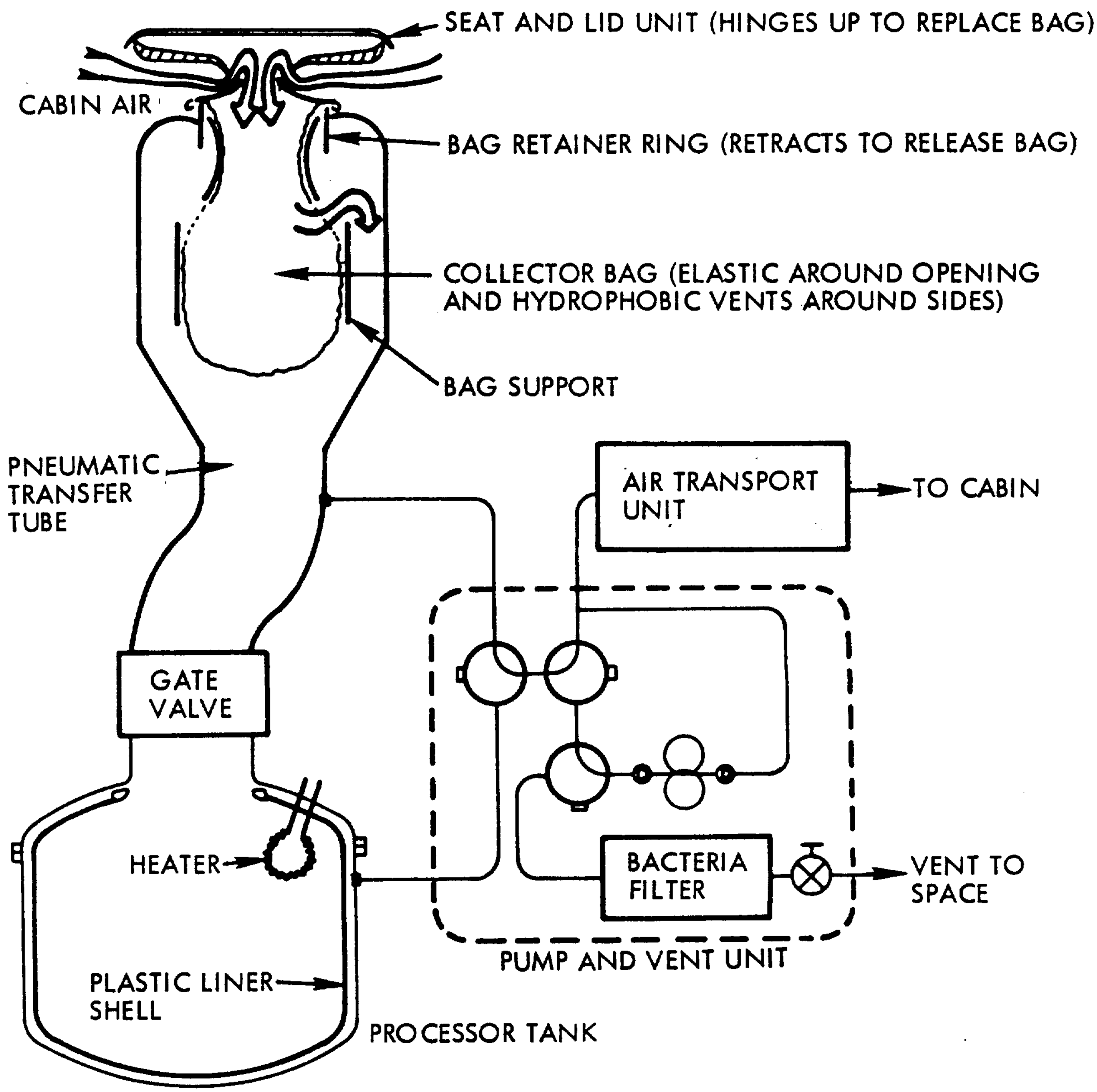


Figure 3-38. Automated Bag System

Automated Bag System Engineering Data

Fixed Weight (FW in lb)		Figure 3-39
Collector unit	8.4N	
Pump and vent unit	5.0N	
Processor	21.0N	
Bag dispenser	2.0N	
Bag cabinet	0.000833CR	
Liner rack	0.0027CR	
Air transport unit (See breakdown in Chemical Toilet Systems engineering data)	$(12.1+3.8/P^{0.25})N$	
Total FW =	$(48.5+3.8/P^{0.25})N+0.0035CR$	
Fixed Volume (FV in ft^3)		Figure 3-40
Collector	3.4N	
Pump and vent unit	0.8N	
Processor	6.0N	
Bag dispenser	0.1N	
Bag cabinet	0.00061CR	
Liner rack	0.00667CR	
Air transport unit	2.25N	
Total FV =	12.55N+0.0073CR	
Expendable Weight (EW in lb/day)		
Bags	0.05C	
Liners	0.000667C	
Filter elements	0.0033C	
Odor cartridges	0.1C	
Total EW =	0.154C	
Expendable Volume (EV in ft^3/day)		
Bags	0.000555C	
Liners	0.00667C	
Filter elements	0.000056C	
Odor cartridges	0.0025C	
Total EV =	0.0098C	
Weight of Atmosphere Lost (AL in lb/day)		Figure 3-41
Venting loss	0.015C	
Leakage loss= (leakage rate per unit length)(length) 0.00278P(3N)	0.00834PN	
Total AL =	0.015C+0.00834PN	
Power, Maximum (PM in watts)		Figure 3-42
Pump	30.0	
Heater	4.0C	
Fan (See Appendix A)	$382.0/P^{0.5}$	
$PM^* = PM_F + PM_H$, Total PM =	$4.0C+382.0/P^{0.5}$	

*Pump is not on when heater and fan operate

Power, Average (PA in watt-hours/day) — Figure 3-43

PA_X = (use time/man-day)(PM_X)C

Pump	0.5 (30)C =	1.5C
Heater	17.5 (4)C =	70.0C
Fan	$0.1(382.0/P^{0.5})C=$	$\underline{38.2C/P^{0.5}}$
	Total PA =	$(71.5+38.2/P^{0.5})C$

Cooling from atmosphere, peak (Q_{CP} in Btu/minute) — Figure 3-44

$Q_{CP} = 0.034PM_F$

$Q_{CP} = 0.034\ (382.0/P^{0.5})$

$\underline{Q_{CP} = 13.0/P^{0.5}}$

Cooling from atmosphere, average (Q_{CA} in Btu/day) — Figure 3-45

Q_{CA} = (use time/man-day)(Q_{CP})C

$Q_{CA} = 6(13.0/P^{0.5})C$

$\underline{Q_{CA} = 78.0C/P^{0.5}}$

Water Vapor rejected to atmosphere (WV in lb/day)

Fecal rate $(T_1-T_2)C_pC = (WV)h_{fg}$

if C_p = 1.22 Btu/lb/1°F

0.33 (97-90)1.22 = 1100 WV

$\underline{WV = 0.01C}$

Initial and resupply period spares weight (SI and SR in lb) — Figures 3-46 and 3-47

See Appendix A for equations and variables

$$FW = (48.5 + 3.8/P^{0.25})N + 0.0035CR$$

$$FW = \text{Factor A} + \text{Factor B}$$

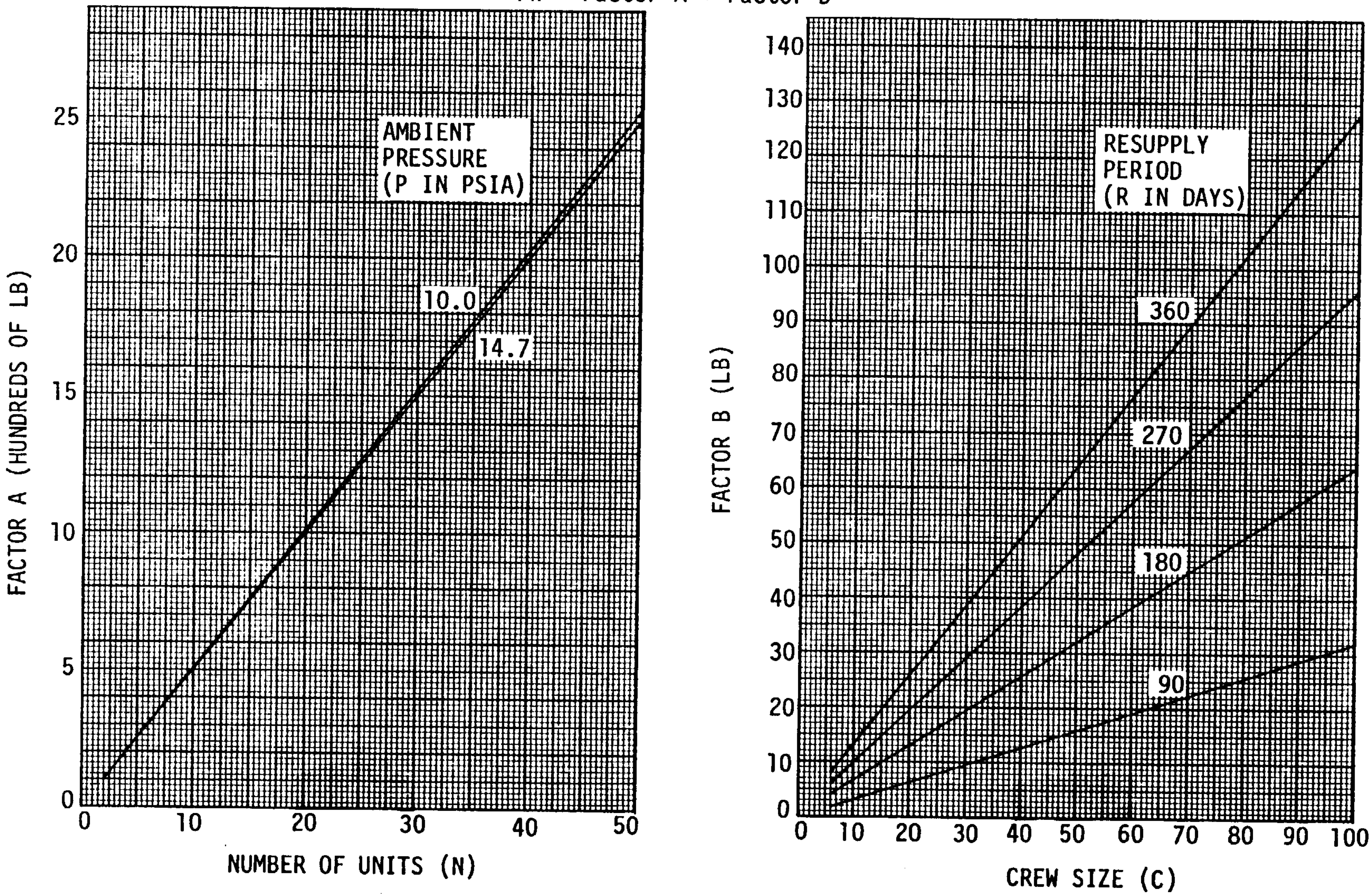


Figure 3-39. Automated Bag System Fixed Weight

$$FV = 12.55\,N + 0.0073\,CR$$
$$FV = \text{Factor A} + \text{Factor B}$$

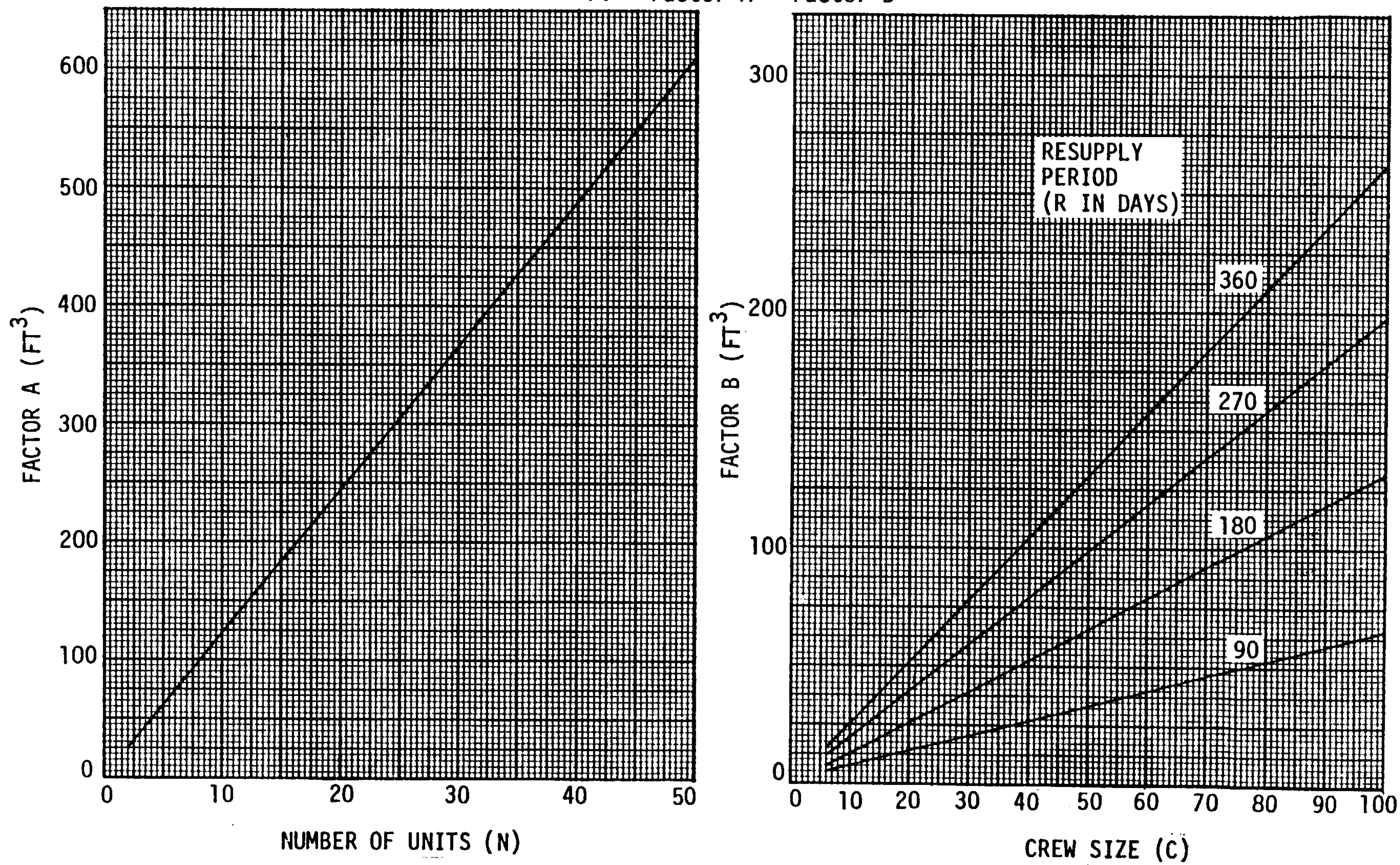


Figure 3-40. Automated Bag System Fixed Volume

AL = 0.015 C + 0.00834 PN
AL = Factor A + Factor B

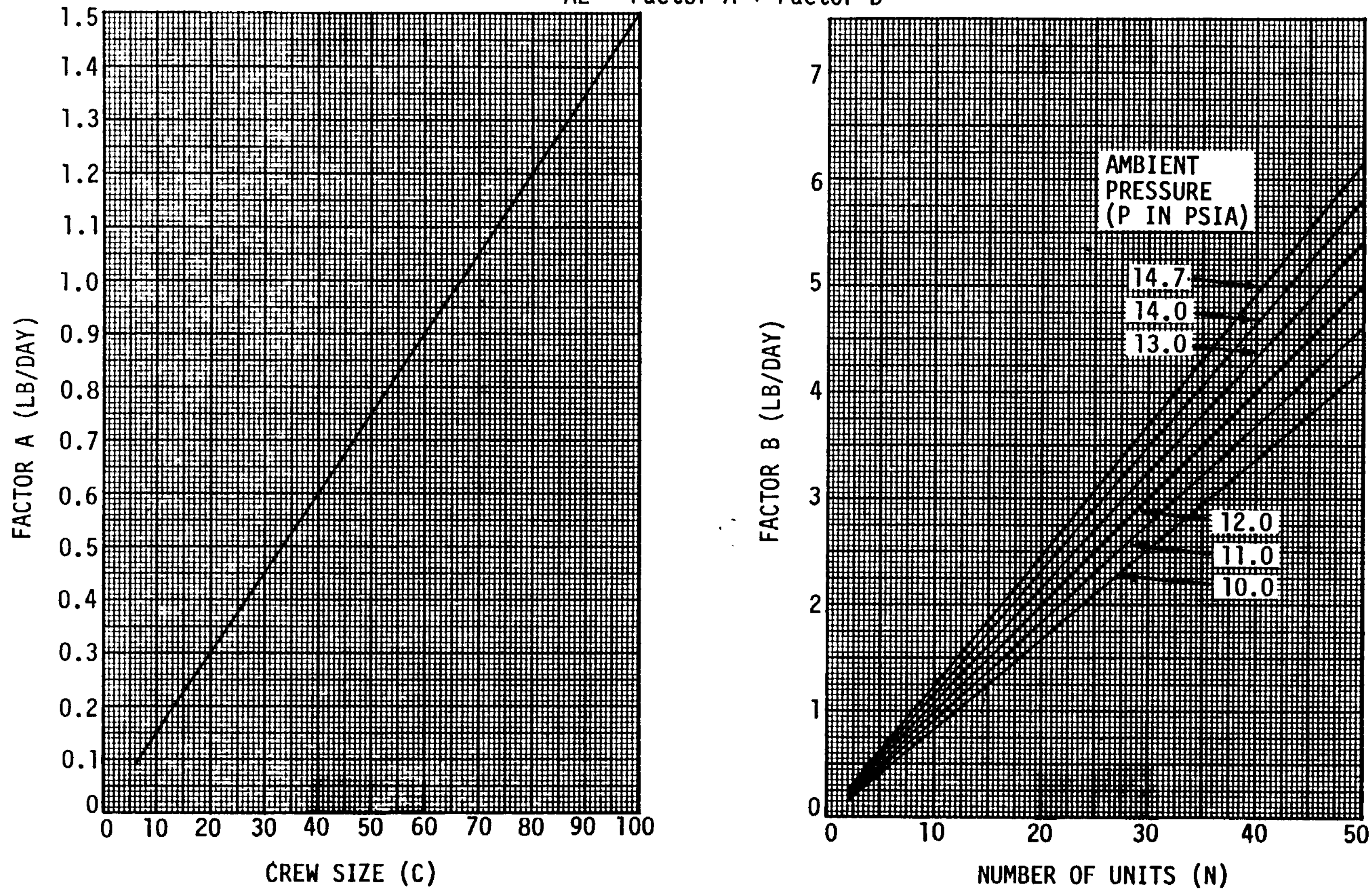


Figure 3-41. Automated Bag System Atmosphere Lost

$$PM = 4.0C + 382.0/P^{0.5}$$

$$PM = \text{Factor A} + \text{Factor B}$$

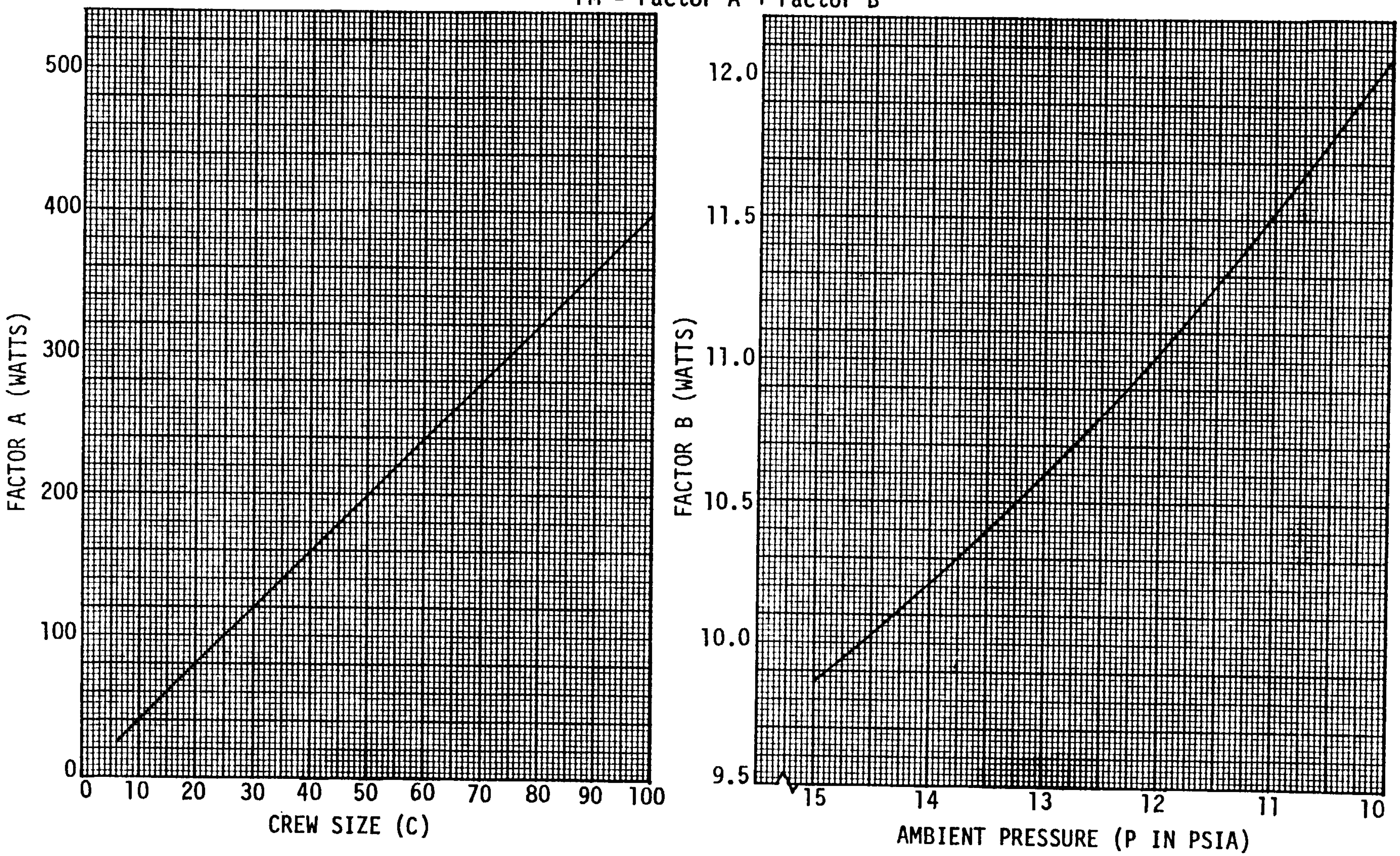


Figure 3-42. Automated Bag System Power, Maximum

$$PA = (71.5 + 38.2/P^{0.5})C$$

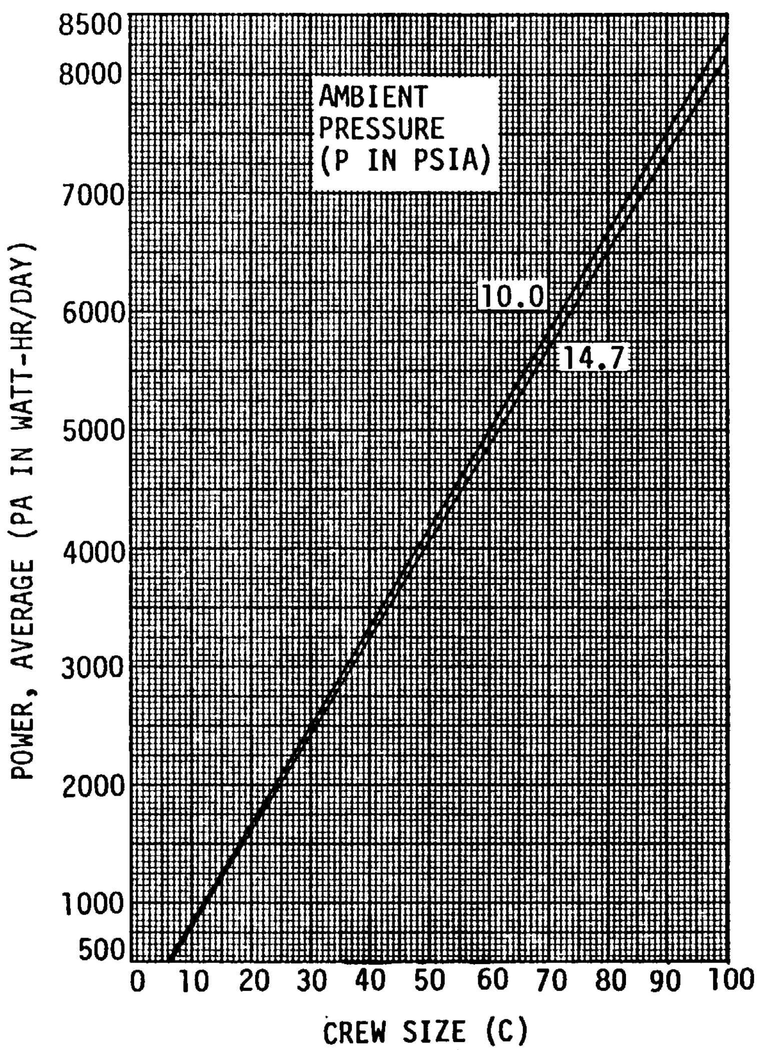


Figure 3-43. Automated Bag System Power, Average

$$Q_{CP} = 13.0/P^{0.5}$$

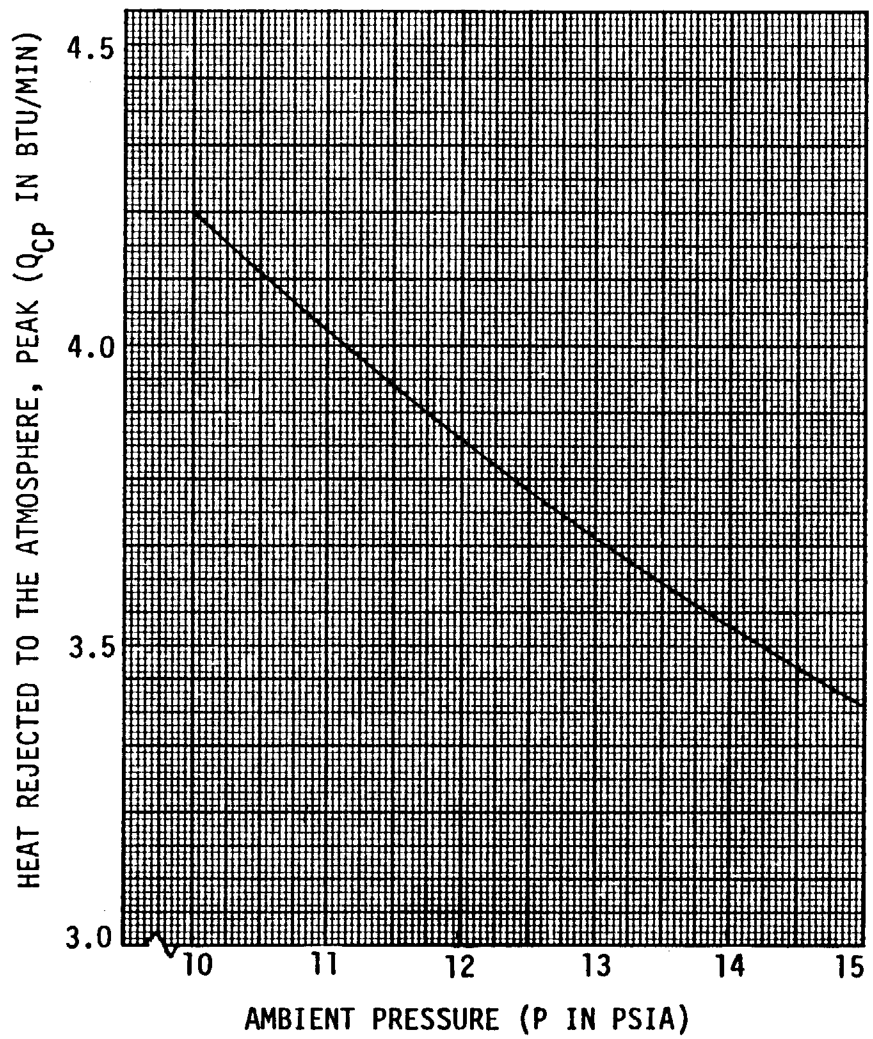


Figure 3-44. Automated Bag System Heat Rejected to the Atmosphere, Peak

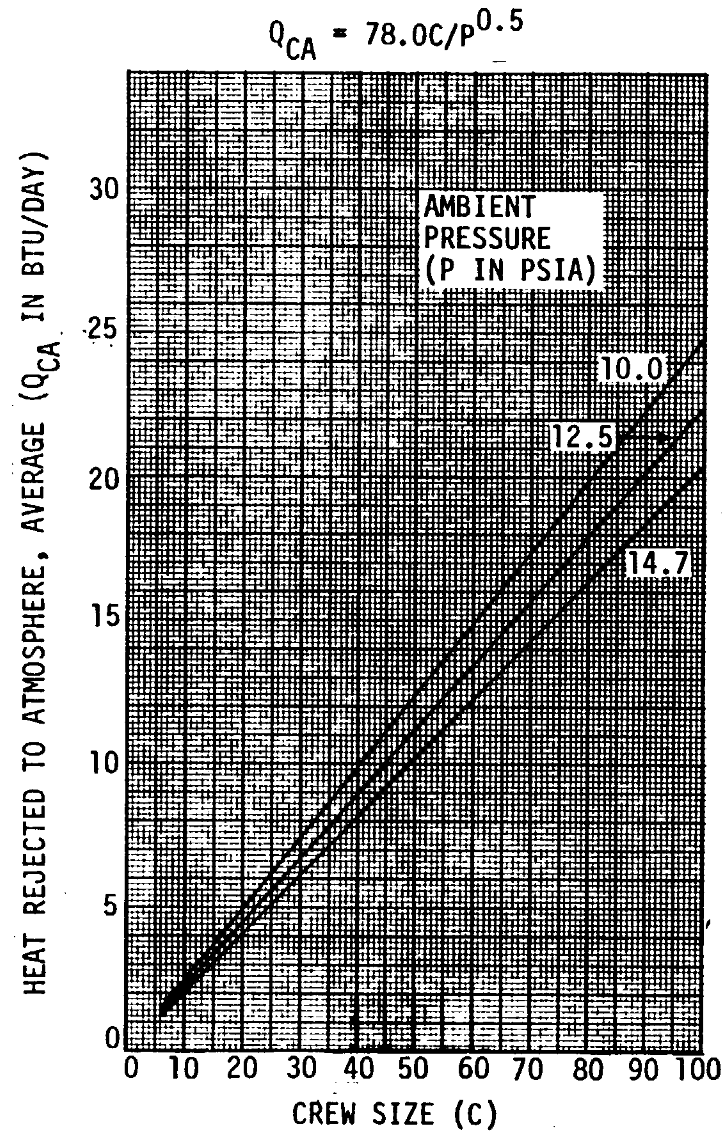


Figure 3-45. Automated Bag System Heat Rejected to the Atmosphere, Average

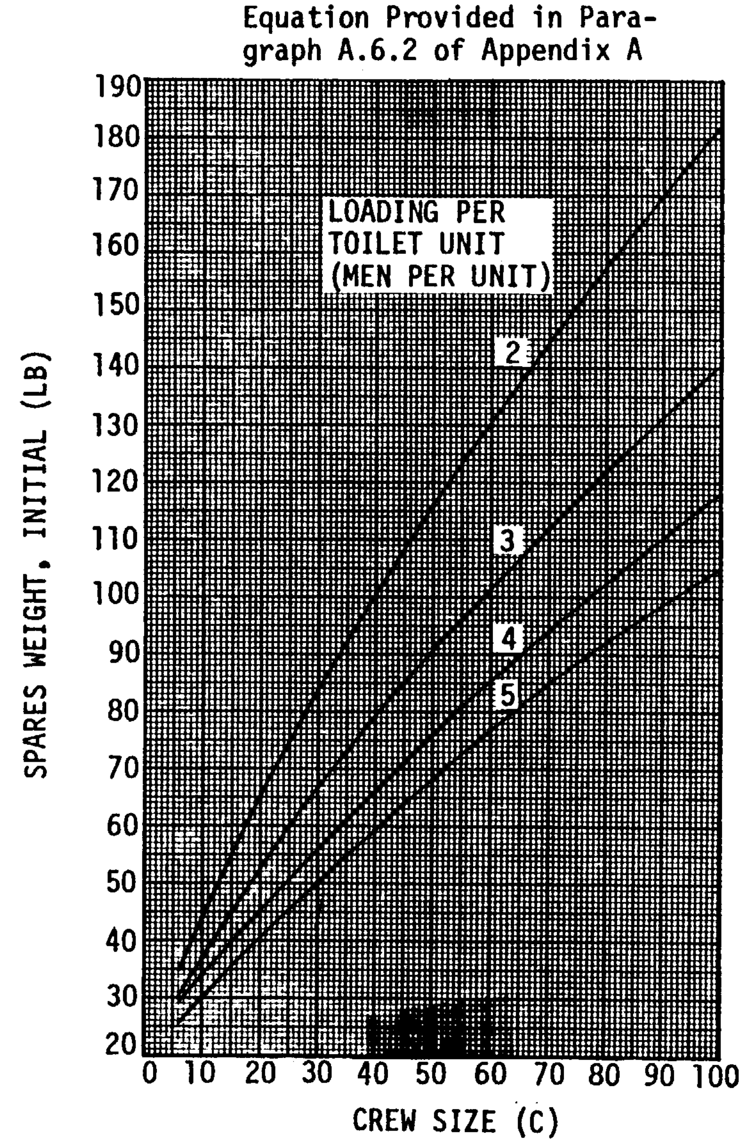


Figure 3-46. Automated Bag System Initial Spares Weight

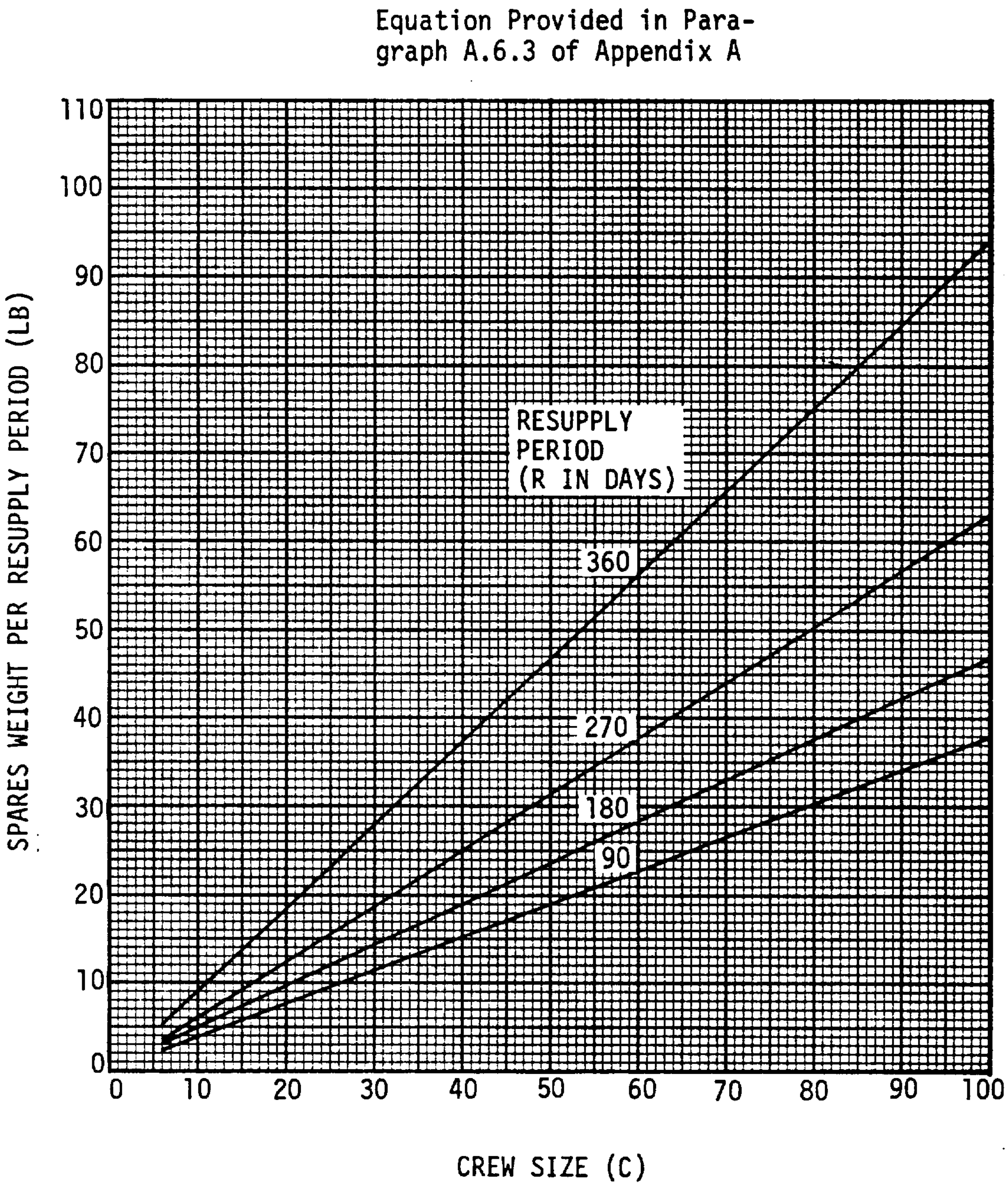


Figure 3-47. Automated Bag System Resupply Period Spares Weight

Hydro-John (Figure 3-48)*

The pneumatic subsystem is used to assist the user in centering himself over the seat opening. It consists of an 850-psig source of nitrogen gas which is regulated to 30 psig before discharging through two small orifices which are aimed at the user's anal area. The gas discharges on command through a normally closed solenoid valve located between the regulating valve and the two orifices. Centering in this manner has the dual effect of assuring that the feces are directed into the blender and that there is a complete seal around the seat opening. The seal is created by the user being in reasonably symmetrical contact with the contoured seat.

The feces and urine are deposited into the unit as shown in Figure 3-48. A steady flow of transport air draws the feces into the blender and the urine into the phase separator. When the user activates the flush cycle after defecation and urination, 4 pounds of flush water are discharged to wash his anal area and the urinal. This wash water is drawn into the system in the same manner as the feces and urine. When a small quantity of water has accumulated in the blender, the feces already present are mixed with the water to form a slurry. After a timed period of mixing, the resulting slurry is pumped out of the unit along with the urine. During the pump-out cycle, flush water continues to flow, thereby washing both the user and the collection system. Following the flush cycle, the user is dried by the transport air which can be heated if desired to hasten the drying process.

The transport air subsystem circulates heated cabin air through openings under the seat into the transport tube and phase separator, through the blower, and discharges it back to cabin atmosphere downstream of the blower after passing it through a bacterial filter-charcoal bed combination. The blower starts when the lid on the unit is raised and before the user is seated. In a zero-gravity environment, the air would serve the purpose of transporting feces away from the user and into the blender blades located at the bottom of the transport tube. In addition, it serves the purpose of drying the user after a flush/wash cycle has been completed. Raising the lid also shuts off a germicidal lamp which radiates to the seat when the unit is not in use and the lid is down.

*Data extracted from Reference 3

Small openings on the urinal allow air to flow in the same manner as it does under the seat except that this air discharges from the urinal directly into the phase separator and then through the blower-bacterial filter-charcoal bed combination before being returned to the atmosphere.

The flush water subsystem consists of an aluminum tank equipped with two 500-watt immersion heaters and two thermo-switches which automatically maintain the 16 pounds of water in the tank at 95(±5)°F. Water is admitted to the tank by connecting the source to a quick disconnect on the back of the unit. All water entering the tank is filtered through a sintered metal filter. There is an additional quick-disconnect on the back of the unit which allows for a gravity fill admission of Wescodyne F-53, a germicidal agent, to the water tank.

Hydro-John Engineering Data

Voltage = 115 Vac

Expendable materials
Provides expendable materials for 1000 operations

Flush solution capacity
Four bacteriocide water solution flushes of four pounds each are available before the system requires refilling.

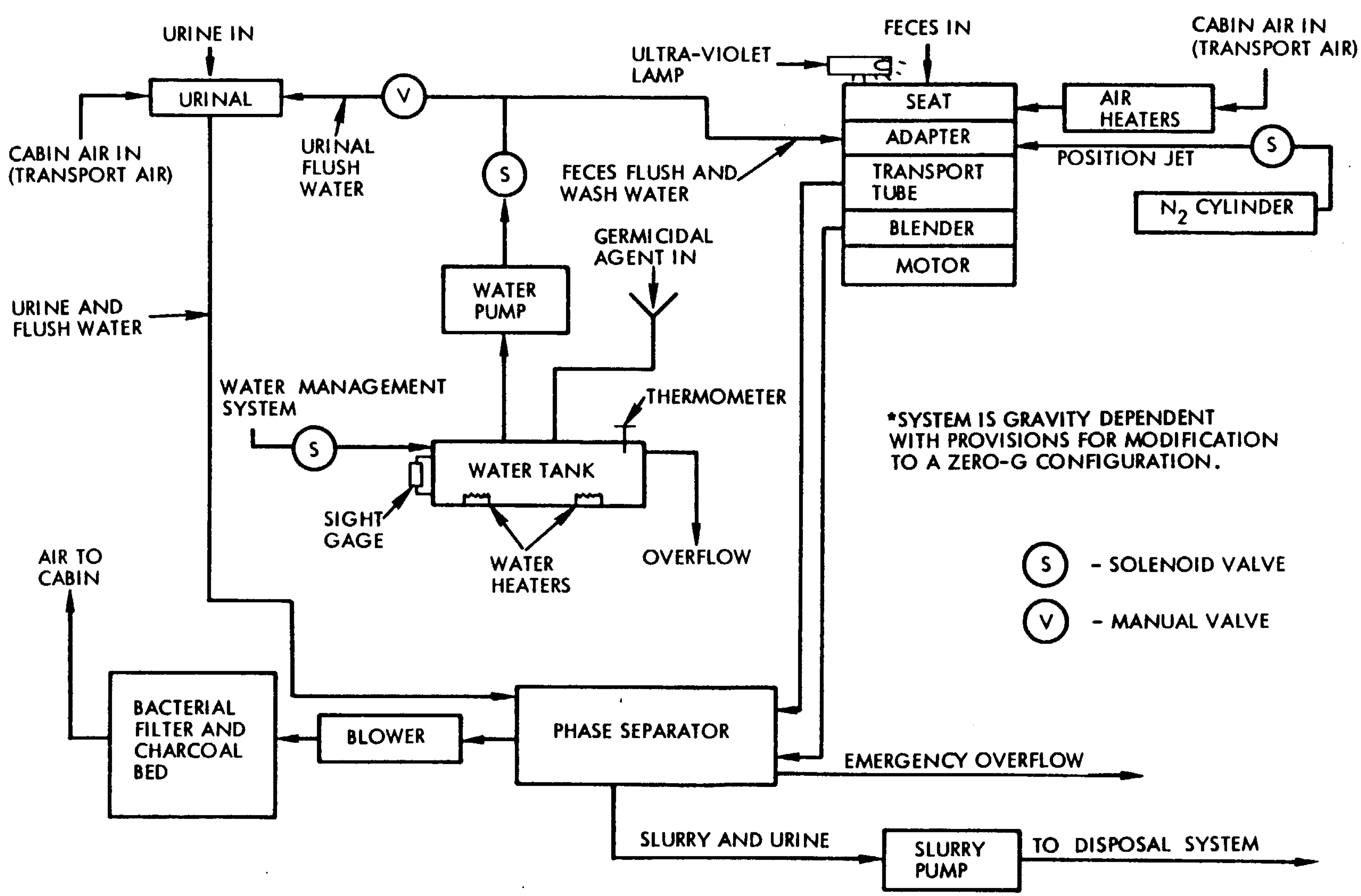


Figure 3-48. Hydro-John Prototype System*

Fecal Collection Module (Figure 3-49)*

The fecal collection module is a two stage collector in which no attempt is made to recover the fecal water. The toilet has a molded seat and restraining harness to hold the user in place. The seat is mounted on a fluid manifold, which is, in turn, mounted upon a vacuum isolation valve. This valve separates the collection and storage area from the flush area. Orifices are provided in the manifold so that impinging jets of air can be employed by the user to aid in centering his anus over the collection hole and also for detaching feces from the anal perimeter after defecation is completed. A ducted blower draws 60 lbs/hr of cabin air over a heater, which heats the air to 120°F and passes it through the collector. This air passes through a liquid/gas separator, a bacteria filter, and activated charcoal before being discharged into the cabin atmosphere. Feces are pneumatically entrained by the air flow, drawn into a rotating slinger in the collector, and flung against the collector surface.

After completion of defecation, the vacuum isolation valve is closed. The collector is evacuated to less than one psia by a compressor which returns the air to the cabin through the previously described filters. This is done to minimize the loss of cabin air to space. The collector is then exposed to space vacuum for drying and control of the feces. The feces are dried under vacuum at ambient temperature. This prevents proliferation of bacterial and microbial growth during the evacuated period, which constitutes 85 percent of the operating time. The cabin is protected from the airborne bacteria in the collector by the directional air flow when the vacuum isolation valve is open.

During the flush cycle, 1.75 pounds of silver ion dosed water, cooled to 100°F in an accumulator/cooler, are sprayed on the user's anal area for 30 seconds. Warm air is then directed on the anal area for drying. Since the vacuum isolation valve is closed, the flush water is transferred by the separator to the processing subsystem. The water does not mix with the feces. The bowl flush is initiated upon closure of the toilet cover. A measured quantity of 1.75 pounds of water at 100°F and 30 psi rinses the bowl for thirty seconds.

*Data extracted from Reference 2

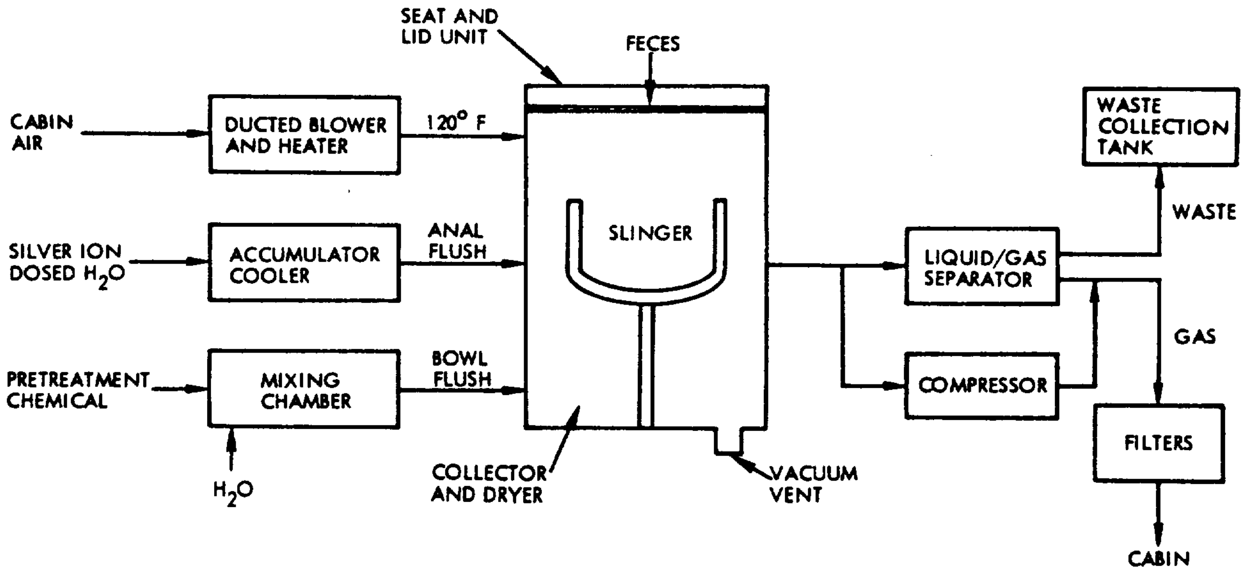


Figure 3-49. Fecal Collection Module

Fecal Collection Module Engineering Data

Fixed Weight (FW in lb)

Toilet	45.0N
Control	13.4N
Fan and pump	8.0N
Compressor	38.0N
Heater	2.0N
Accumulator-cooler	18.2N
Mixing chamber	0.5N
Valves	18.2N
Total FW =	143.3N

Fixed Volume (FV in ft^3)

Toilet	14.60N
Control	0.71N
Fan and pump	0.09N
Compressor	0.45N
Heater	0.25N
Accumulator-cooler	0.12N
Mixing chamber	0.01N
Valves	0.77N
Total FV =	17.0N

Water Vented overboard (WV in lb/day)

WV = (0.25 lbs/man-day)C

WV = 0.25C

Water Influx from WMS (WI in lb/day)

WI = (3.3 lbs/man-day)C

WI = 3.3C

Process Rate, average (PR in lb/hr)

PR = 3.0N

Spares Weight (SW in lb)

Toilet	45.0N
Control	13.4N
Fan and pump	8.0N
Compressor	38.0N
Heater	2.0N
Accumulator-cooler	13.2N
Mixing chamber	0.3N
Valves	13.6N
Total SW =	133.5N

Spares Volume (SV in ft^3)

Toilet	14.60N
Control	0.71N
Fan and pump	0.09N
Compressor	0.45N
Heater	0.25N
Accumulator-cooler	0.12N
Mixing chamber	0.01N
Valves	0.35N
Total SV =	16.58N

3.3 URINE AND FECES SPECIMEN COLLECTION AND PROCESSING

3.3.1 Urine Specimen Requirements.

- The capacity to collect urine specimens shall be as follows:

amount:	1.1 lb per urination maximum, 0.88 nominal
frequency:	3 to 7 urinations per man-day, 5 nominal
quality:	pH; 4.5 to 8.0 specific gravity; 1.002 to 1.035, 1.01 nominal
constituents:	electrolytes, nitrogen compounds, vitamins, acids, organic compounds, hormones

- The capacity to process urine specimens shall be as follows:

amount:	7.7 lb per man-day maximum, 4.4 nominal
frequency:	3 to 7 urinations per man-day, 5 nominal
quality:	pH; 4.5 to 8.0 specific gravity; 1.002 to 1.035, 1.01 nominal

- Viability of organisms and biochemical activity of specimen shall be maintained.
- Labile chemical constituent loss should be prevented.
- Specimen contamination from external sources shall be avoided.
- Specimen analysis shall be completed onboard the spacecraft within 48 hours of collection. After analysis, the specimens shall be disposed of in the normal urine and feces collection units.
- Sensory (visual, olfactory, and tactile) isolation from collected specimens shall be provided.
- The specimen collection process shall not expose personnel to the space environment.

3.3.2 Feces Specimen Requirements.

- The capacity to collect feces specimens from defecations shall be as follows:

amount:	wet weight; 0.66 lb/use maximum, 0.33 lb/use nominal dry weight; 0.275 lb/use maximum, 0.08 lb/use nominal
frequency:	0 to 2 times per man-day, 1 nominal
characteristics:	H_2O content; 65 to 90%, 75% nominal pH; 6.9 to 7.7 specific gravity; 1.0 to 1.4, 1.2 nominal
constituents:	water, electrolytes, nitrogen compounds, organic compounds, vitamins, amino acids

- Provisions shall be incorporated to provide for the collection of specimens of diarrhetic defecations.
- Isolation shall be maintained between feces samples which consist of the feces from one normal defecation.
- Viability of organisms and biochemical activity of the specimen shall be maintained.
- The capacity to process feces specimens shall be as follows:

amount:	wet weight; 0.66 lb/use maximum, 0.33 lb/use nominal dry weight; 0.275 lb/use maximum, 0.08 lb/use nominal
frequency:	0 to 2 defecations per man-day, 1 nominal
quality:	pH; 6.9 to 7.7 specific gravity; 1.0 to 1.4, 1.2 nominal
dry constituents:	electrolytes, nitrogen compounds, vitamins, amino acids, fatty acids, organic compounds

- Specimen contamination from external sources shall be avoided.
- Specimen analysis shall be completed onboard the spacecraft within 48 hours of collection. After analysis, the specimens shall be disposed of in the normal urine and feces collection units.
- The specimen collection process shall not expose personnel to the space environment.
- The fecal smear shall be removed from the anal area after each defecation. The cleansing agents should be non-irritating, non-toxic, non-volatile, non-explosive, non-flammable, and shall be evaluated as to effect on microbial flora, but shall allow an adequate level of sebum to be maintained.
- Handling of specimens shall not require direct skin contact.
- Personal hygiene equipment should allow feces and urine specimens to be collected as nearly automatically as possible in the normal course of performing elimination functions.

3.3.3 Concept Descriptions and Engineering Data. The urine and feces specimen collection and processing concepts discussed in this section are: a) the Urine Processor and Bag, b) Feces Bags, and c) the Specimen Refrigerator.

Urine Processor and Bag (Figure 3-50)

A funnel shaped urinal with an adequately sized opening is attached to a plenum in which a collection bag is secured with a clamp. The air transport unit from the normal urinal is activated, and a valve is used to switch air flows, creating a cabin air sweep into the opening, and thus controlling and transporting the urine into the bag. The bag has hydrophobic patches for separation of urine from air stream and a hydrophilic liner to retain urine. After urination has been completed, the blower is turned off and the plenum cover is removed. The bag is then removed, sealed, and manually transported to the processing unit. The specimen collector is then prepared for further use by installing a new bag and replacing the plenum cover.

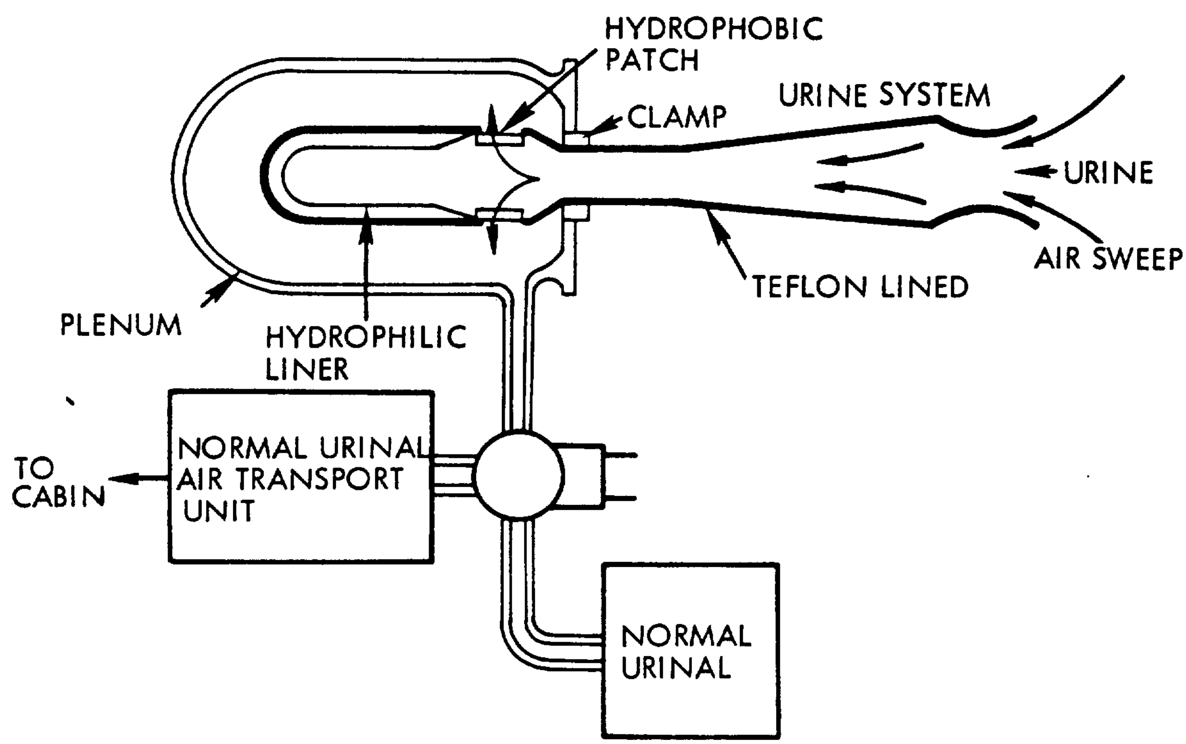


Figure 3-50. Urine Processor and Bag

Urine Processor Engineering Data

Fixed Weight (FW in lb)		Figure 3-51
Aperture cone	$2.5N$	
Bag plenum	$2.0N$	
Ducting (See Appendix A)	$3.2N/P^{0.25}$	
Bag dispenser (See Appendix A)	$0.00089SL$	
Total FW =	$(4.5 + 3.2/P^{0.25})N+0.00089SL$	

Fixed Volume (FV in ft^3)		Figure 3-52
Aperture cone	$0.5N$	
Bag plenum	$0.5N$	
Ducting	$0.2N$	
Bag dispenser	$0.00077SL$	
Total FV =	$1.2N+0.00077SL$	

Expendable Weight (EW in lb/day)

Bags (0.01 each)

$EW = 0.05S$

Expendable Volume (EV in ft^3/day)

Bags (0.00015 each)

$EV = 0.00075S$

$$FW = (4.5 + 3.2/P^{0.25})N + 0.00089\ SL$$

$$FW = \text{Factor A} + \text{Factor B}$$

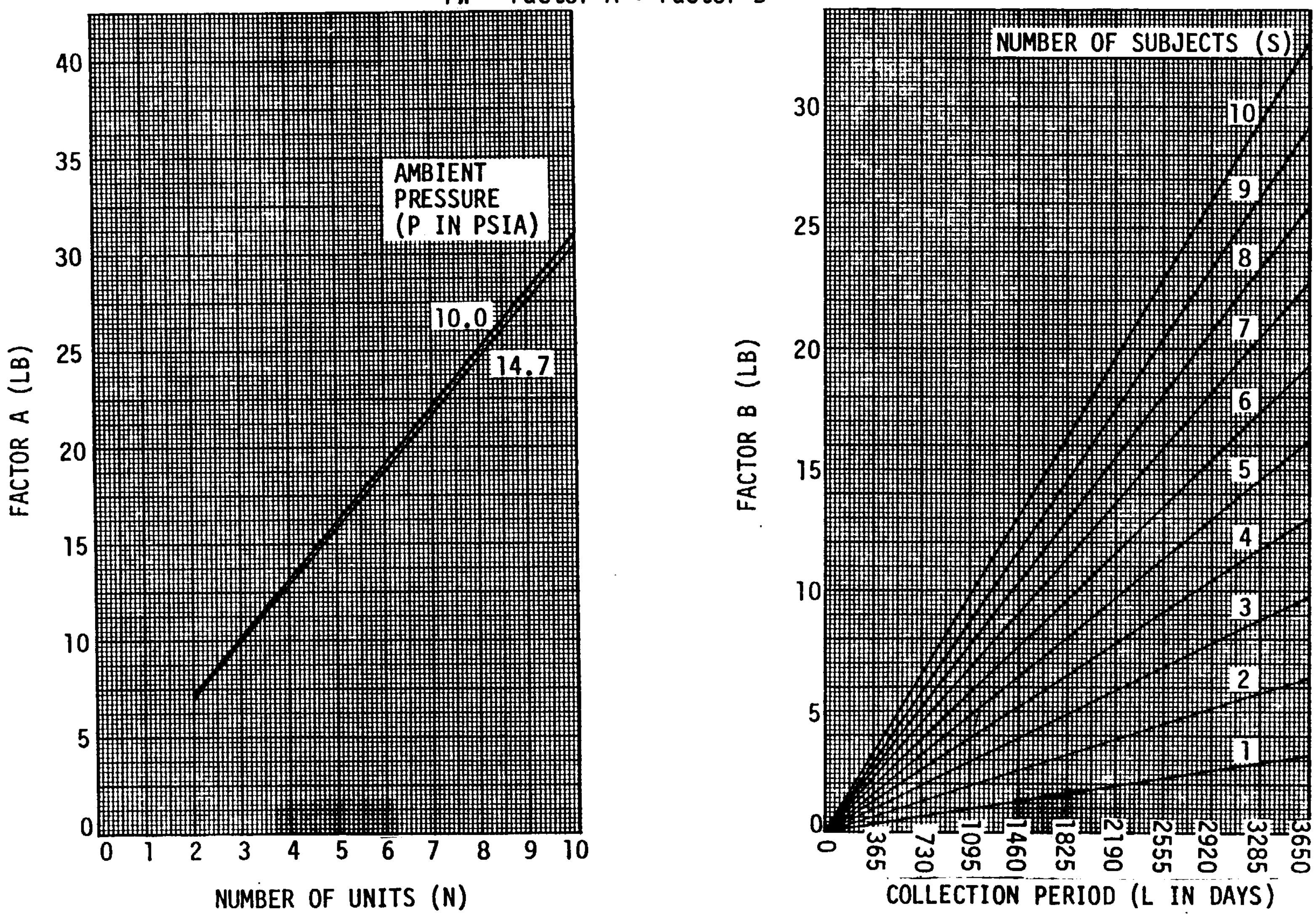


Figure 3-51. Urine Specimen Collection Fixed Weight

$FV = 1.2\,N + 0.00077SL$

$FV = \text{Factor A} + \text{Factor B}$

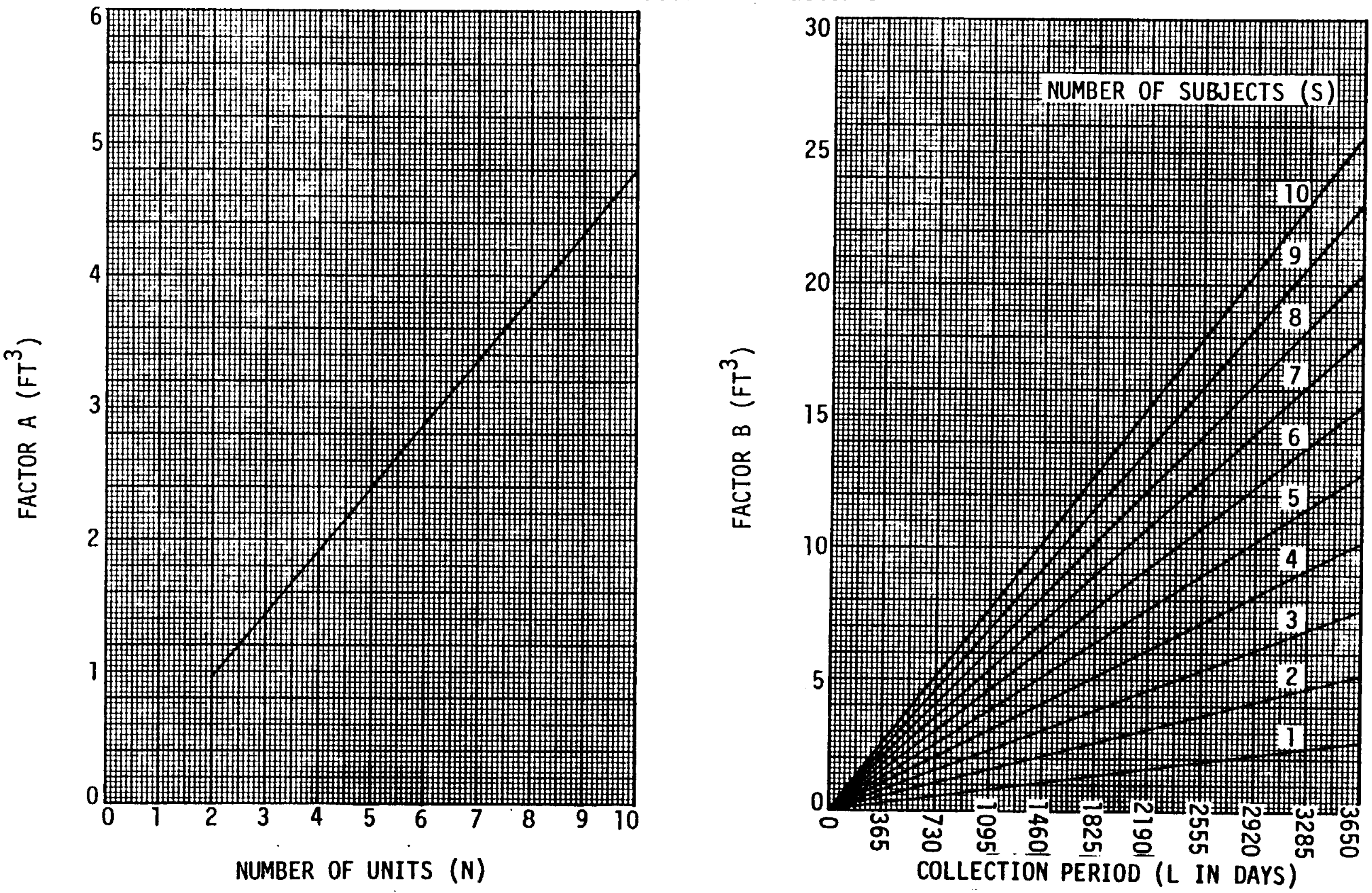


Figure 3-52. Urine Specimen Collector Fixed Volume

Feces Bags (Figure 3-53)

Specially designed collection bags with hydrophobic patches are inserted into the normal feces collection unit. The air transport unit is activated to transport the feces into the bag. After defecation and anal cleansing are completed, the bag is sealed, the blower is shut off, and the specimen is manually transferred to the processor.

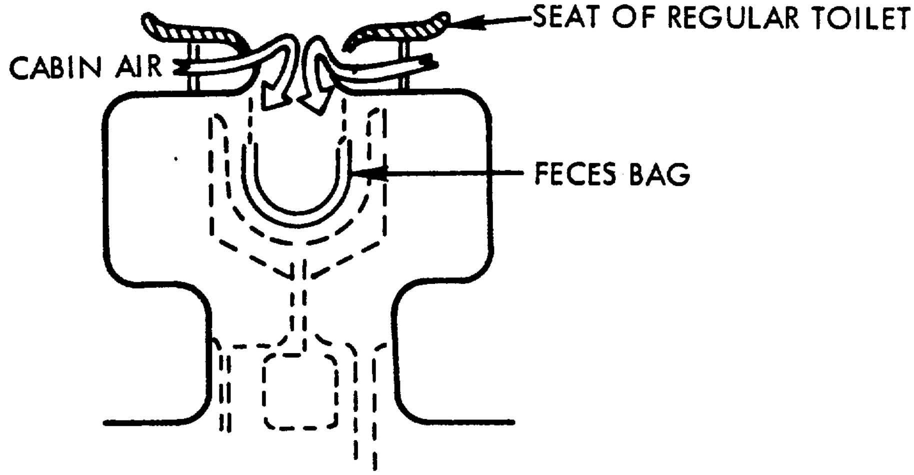


Figure 3-53. Feces Bag Inserted in Toilet

Feces Bags Engineering Data — Figure 3-54

Fixed Weight (FW in lb)

Dispenser

$FW = 1.152FV$ (See Appendix A)

$FW = 1.152\ (0.0013SL)$

$\underline{FW = 0.0015SL}$

Fixed Volume (FV in ft^3) — Figure 3-55

Dispsenser

$\underline{FV = 0.0013SL}$

Expendable Weight (EW in lb/day)

Bags

$\underline{EW = 0.1S}$

Expendable Volume (EV in ft^3/day)

Bags

$\underline{EV = 0.0011S}$

$FW = 0.0015SL$

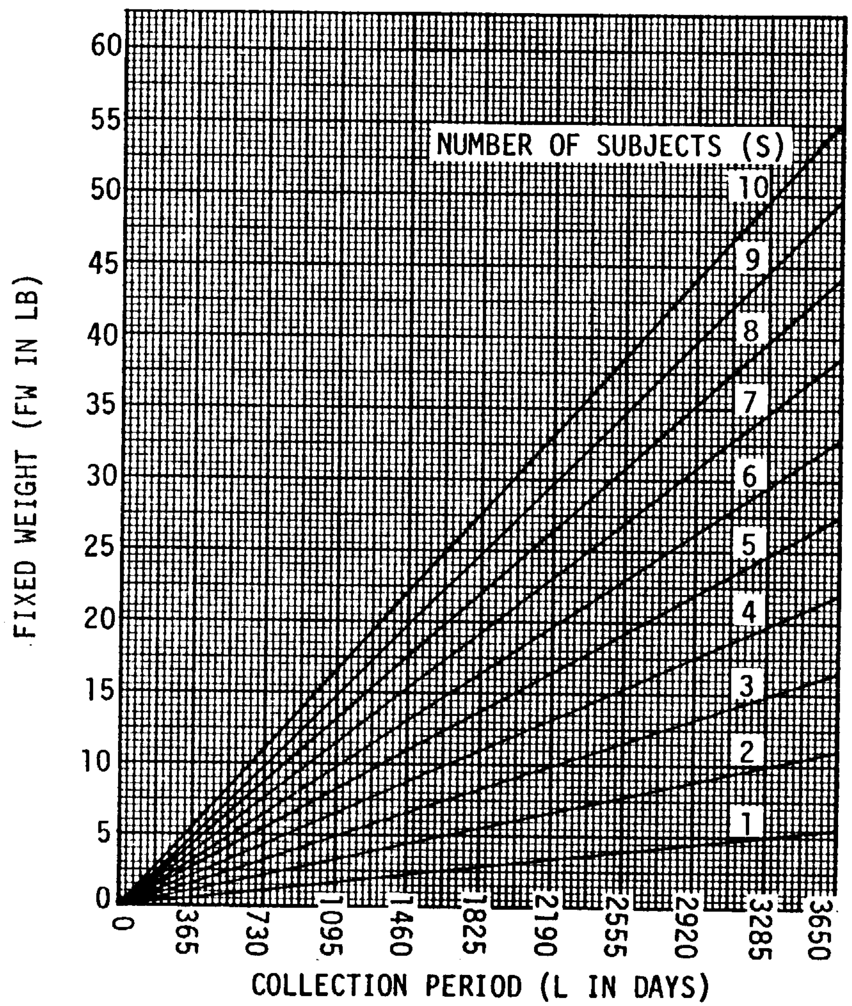


Figure 3-54. Feces Specimen Collector Fixed Weight

$FV = 0.0013SL$

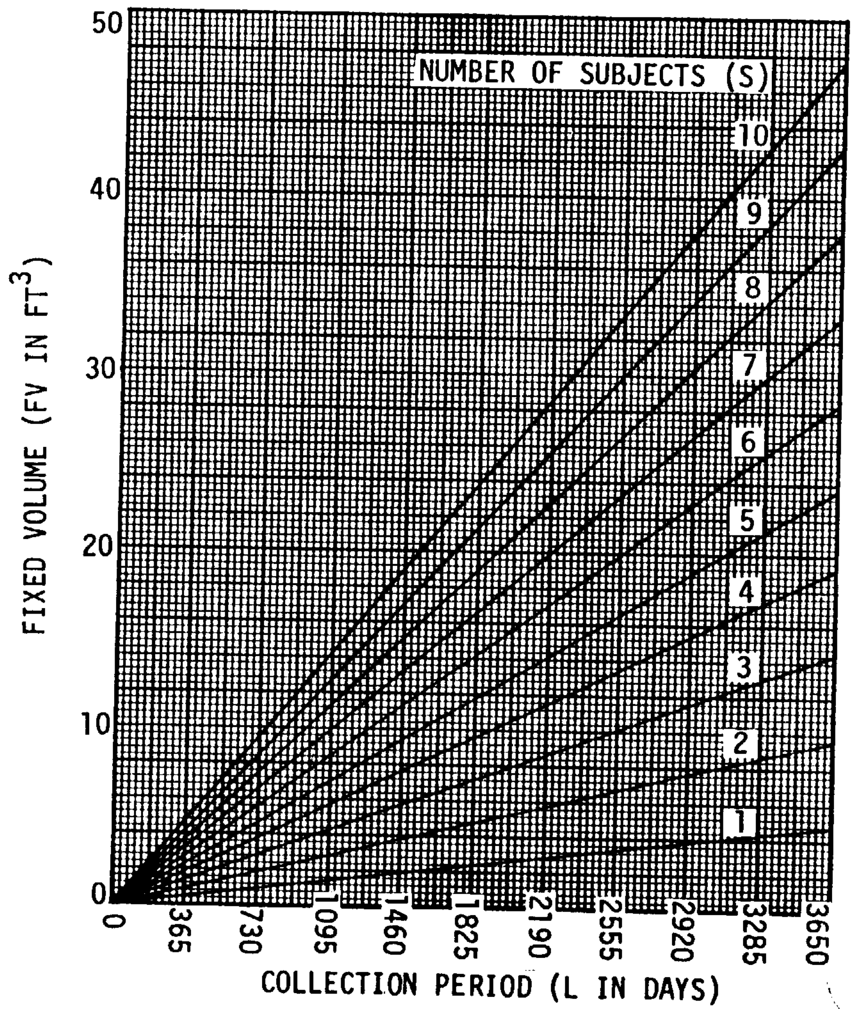


Figure 3-55. Feces Specimen Collector Fixed Volume

Specimen Refrigerator (Figure 3-56)

A refrigerator can be used to store collected specimens prior to onboard processing or transfer to earth. The temperature in the refrigerator is maintained between 1°C and 4°C by a thermostatically controlled heat pump which rejects heat to the heat transport system. Internal ducting and a small circulation fan are used to provide convective cooling. A vacuum jacket is used to minimize the heat leak from ambient cabin atmosphere.

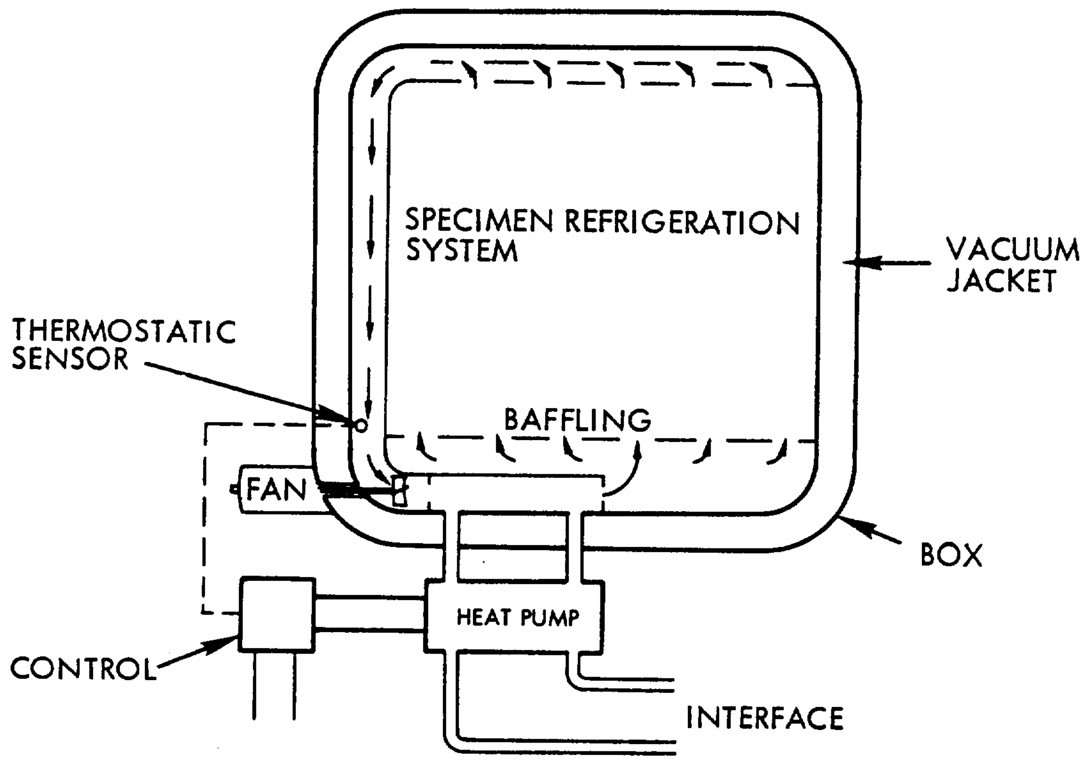


Figure 3-56. Specimen Refrigerator

Specimen Refrigerator Engineering Data

Fixed Weight (FW in lb)

Box	2.33S
Heat pump	4 + 2S
Control	0.5
Circulation fan	0.2
Heat exchanger	0.4 + 0.2S
Total FW =	5.1 + 4.53S

Fixed Volume - External (FV in ft^3)

Box		0.5S
Mechanics		0.5
	Total FV =	0.5 + 0.5S

Power, Maximum (PM in watts)

Fan		5.0
Heat pump		33.3S
	Total PM =	5.0 + 33.3S

Power, Average (PA in watt-hours/day)

Fan		5.0
Heat pump		
264S Btu/day (See below)		3.23S
	Total PA =	5.0 + 77.52S

Cooling from liquid loop, peak (Q_{LP} in Btu/minute)

if COP = peak heat from box/PM_{HP} = 0.667 (Note: PM_{HP} = power of heat pump)

and $Q_{LP} = PM_{HP}$ + peak heat from box

then Q_{LP} = 33.3S (1.0 + 0.667) watts

Q_{LP} = 3.16S

Cooling from liquid loop, average (Q_{LA} in Btu/day)

if: heat from box, average per day = Q_{BA}

then: Q_{BA} = (specimen mass per day)Cp (T_1-T_2)

Q_{BA} = (0.25S+4.40S)(1.0)(70-32)

Q_{BA} = 176S Btu/day

but: COP = 0.667 = Q_{BA}/PA_{HP} (Note: COP = coefficient of performance of refrigerator)

so: PA_{HP} = 1.5 Q_{BA} = 264S Btu/day

finally:

$Q_{LA} = Q_{BA}+PA_{HP}$

Q_{LA} = 176S+264S

Q_{LA} = 440S

Initial and 180-day resupply period spares weight* (SI and SR in lb)

No. of Subjects	Initial Spares (lb)	Resupply Spares (lb)
2	9.86	0.44
3	12.06	0.55
4	14.26	0.66
5	16.46	0.77

*Refer to Appendix A for equations and variables

3.4 ANAL CLEANSING

3.4.1 Requirement.

- The fecal smear shall be removed from the anal area after each defecation. The cleansing agents should be non-irritating, non-toxic, non-volatile, non-explosive, non-flammable, and shall be evaluated as to effect on microbial flora, but shall allow an adequate level of sebum to be maintained.

3.4.2 Concept Description and Engineering Data.

Wet and Dry Wipes

Wet and dry wipes will be housed in individual dispensers. The crewman initially uses two dry wipes (4" x 4" each) to separate the bolus from the anus and remove the bulk of fecal matter from the perineum. He then uses four wet wipes to clean the anal area, and four more dry wipes to dry the area. All wipes are disposed of into the feces collector to be processed with the feces. A cabinet is provided on board to store the wipes which are delivered each resupply period.

Wet and Dry Wipe Engineering Data

Fixed Weight (FW in lb)			Figure 3-57
Storage cabinet (from Appendix A)			
(1.152) FV_{SC} = 0.00195CR(1.152)=		0.00225CR	
Dispensers		2.0N	
	Total FW =	0.00225CR+2.0N	
Fixed Volume (FV in ft^3)			Figure 3-58
Storage cabinet		0.00195CR	
Dispensers		0.1N	
	Total FV =	0.00195CR+0.1N	
Expendable Weight (EW in lb/day)			
Wet wipes		0.04C	
Dry wipes		0.006C	
	Total EW =	0.046C	
Expendable Volume (EV in ft^3/day)			
Wet wipes		0.00069C	
Dry wipes		0.00103C	
	Total EV =	0.00172C	

FW = 2.0N + 0.00225CR

FW = Factor A + Factor B

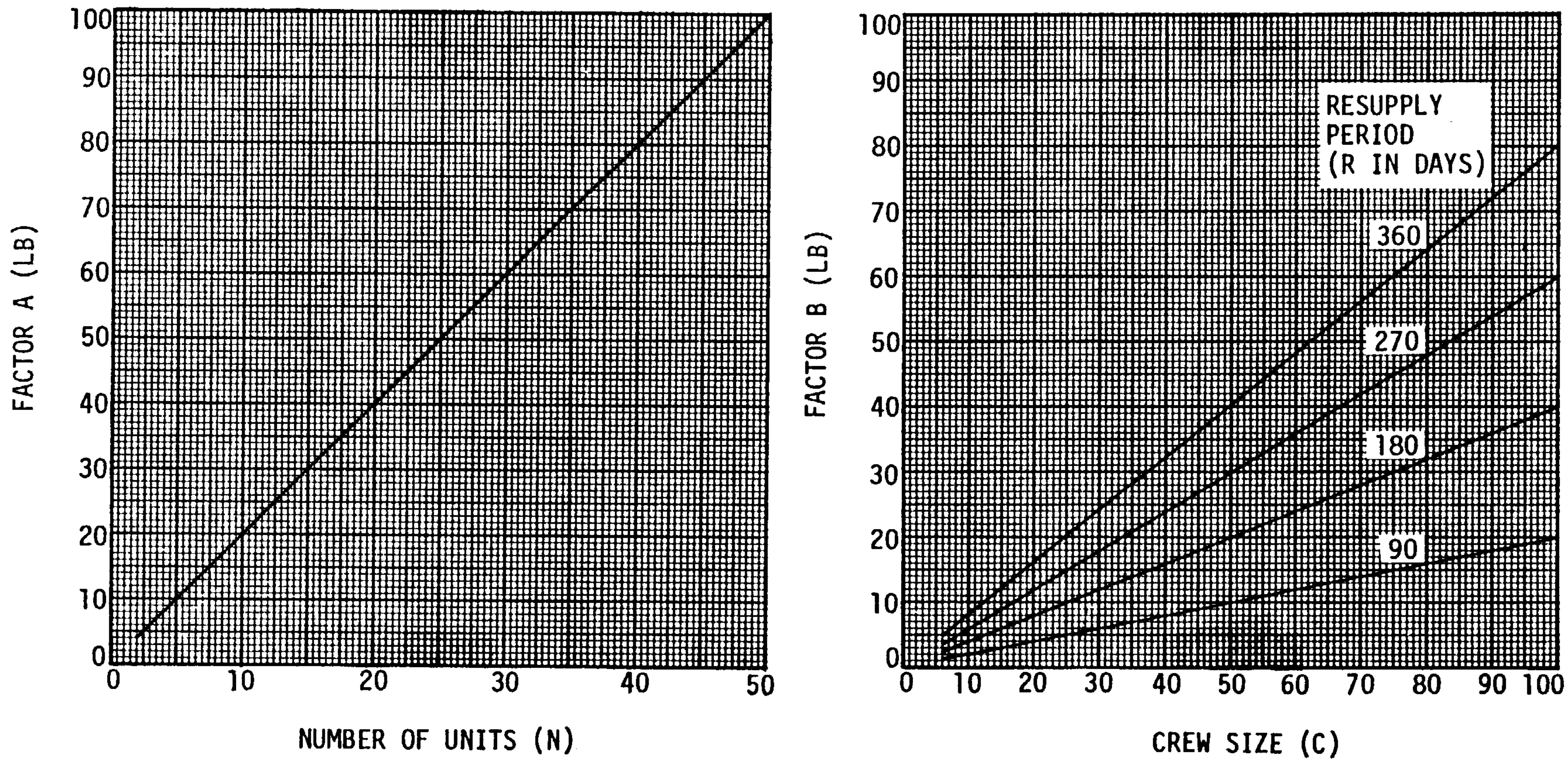


Figure 3-57. Anal Cleansing System Fixed Weight

$$FV = 0.1N + 0.00195CR$$
$$FV = \text{Factor A} + \text{Factor B}$$

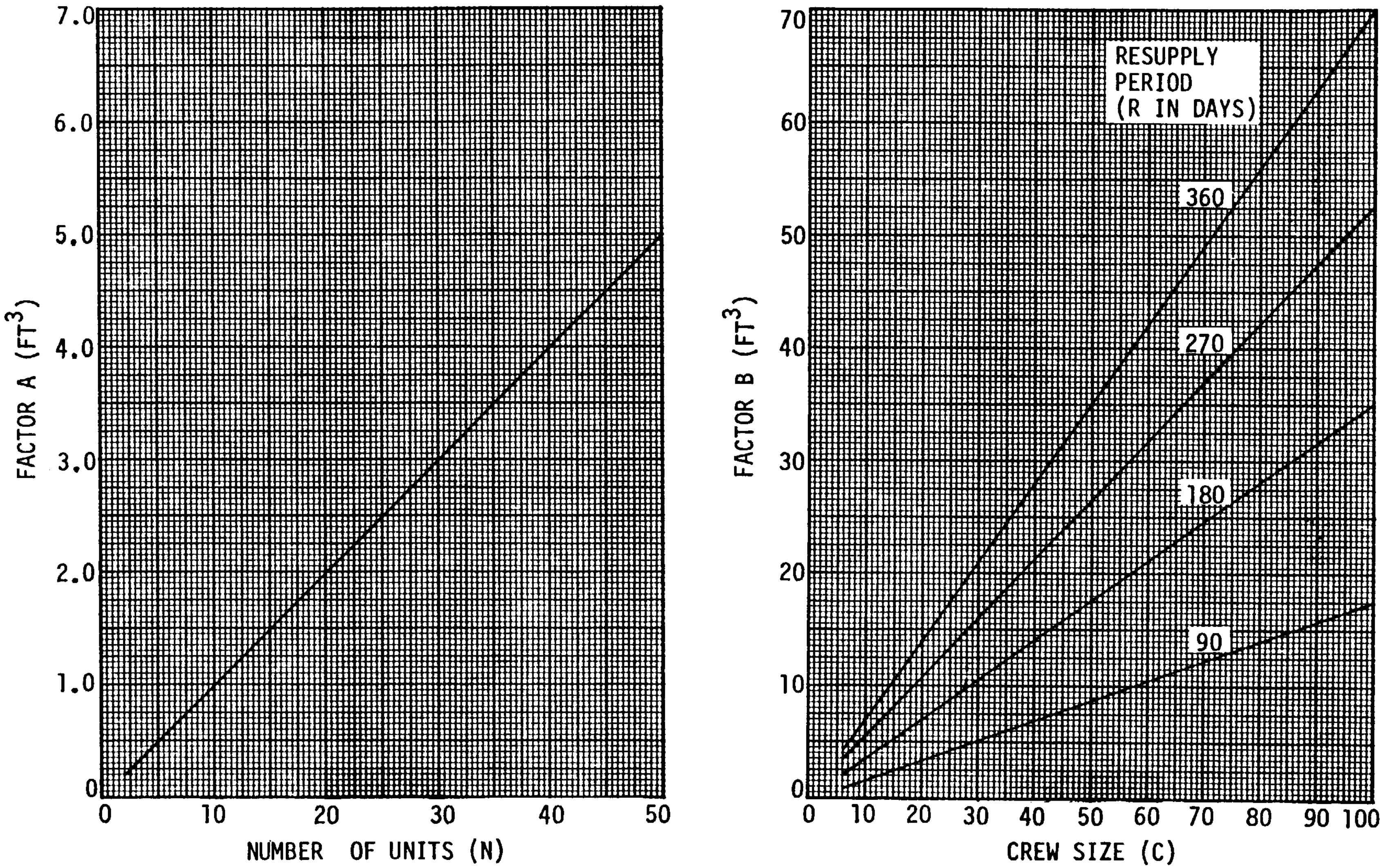


Figure 3-58. Anal Cleansing System Fixed Volume

3.5 VOMITUS COLLECTION AND PROCESSING

3.5.1 Requirements.

- The minimum capacity to collect vomitus shall be as follows:
  - Wet: 0.056 cubic feet per man-day
  - Dry: 17.6 ounces per man-day
- The capacity for vomitus processing equipment shall be 0.056 cubic feet per occurrence.
- Microbial and chemical activity shall be permanently eliminated.

3.5.2 Concept Descriptions and Engineering Data. The vomitus collection and processing concepts discussed in this section are: a) Disposable Collectors, b) Disposable Lining Collectors, and c) Vomitus Cleaning Agents.

Disposable Collector (Figure 3-59)

The lightweight plastic adaptor fits into the toilet seat of the feces collection unit. Holes in the tip of the adaptor provide the air inlet when the adaptor is in use. The top of the adaptor is formed to a crewman's face, effecting a seal over the nose, around the mouth, and under the chin. All vomitus, including that which is expelled from the nasal passages, is thus directed into the feces collection unit. After use, the adaptor is removed and processed for disposal.

Disposable Collector Engineering Data

Fixed Weight (FW in lb) — Figure 3-60

Dispenser

Assume: Metal thickness = 0.02 inches
"LILY CUP" type dispenser is in a square cylinder
Adaptors are 8"x6"x6"
One use/7 man-days
0.5 inch non-nesting lip on adaptor

FW = (density)(thickness)(perimeter)(length)
FW = (0.1)(0.02)(24.0)(0.071CR)
FW = 0.0034CR

Fixed Volume (FV in ft^3) — Figure 3-61

Dispenser

FV = base area (length)
FV = 0.25(0.006CR)
FV = 0.0015CR

Expendable Weight (EW in lb/day)

Adaptors

EW = weight per adaptor(C adaptors/7 days)

EW = 0.1(C/7)

EW = 0.0143C

Expendable Volume (EV in ft^3/day) Figure 3-62

EV = (Volume of first adaptor+[CR/7] Incremental Volume)/R

EV = (0.1667+0.0015CR)/R

EV = 0.1667/R+0.0015C

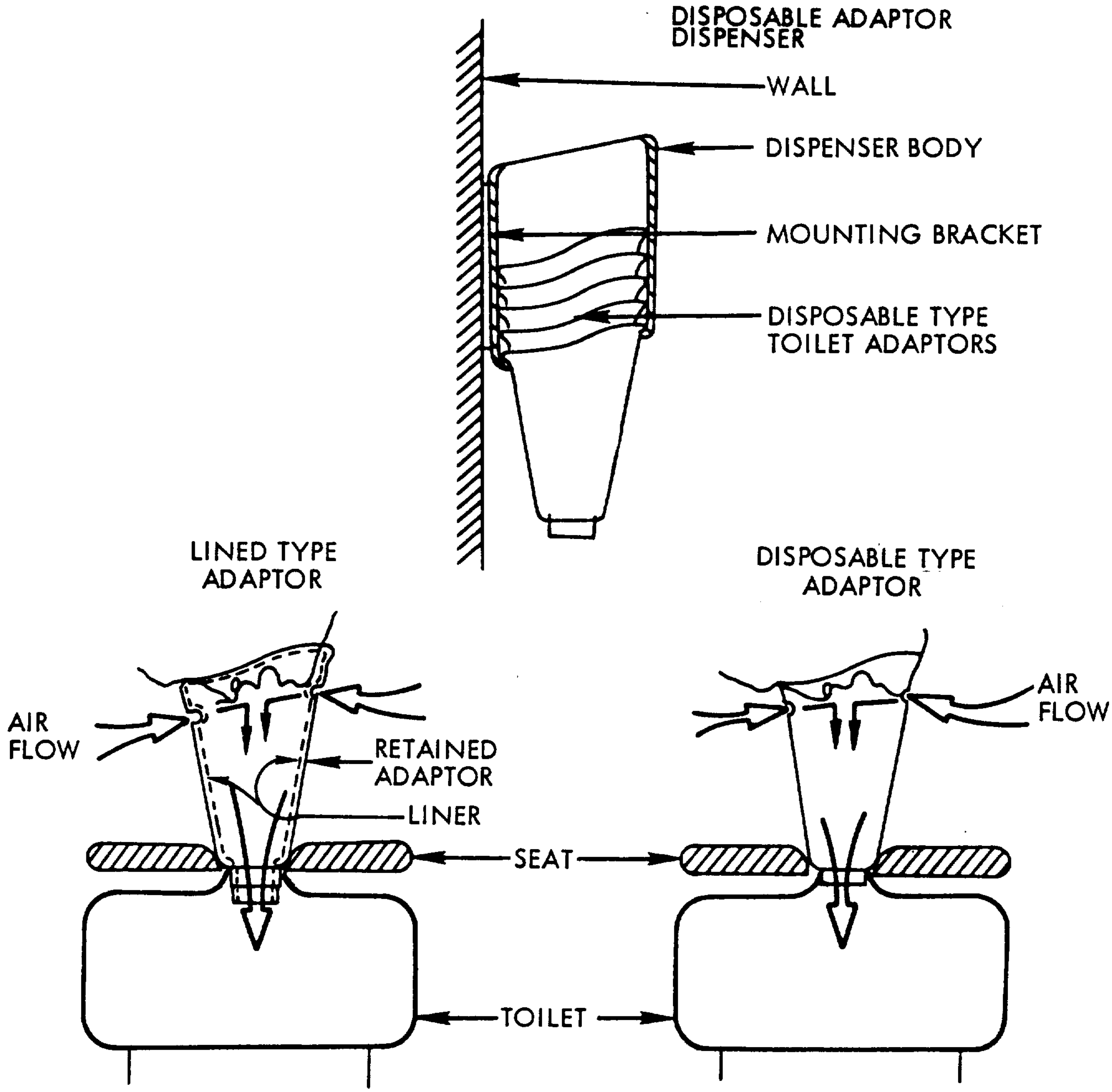


Figure 3-59. Vomitus Collection Toilet Adaptors

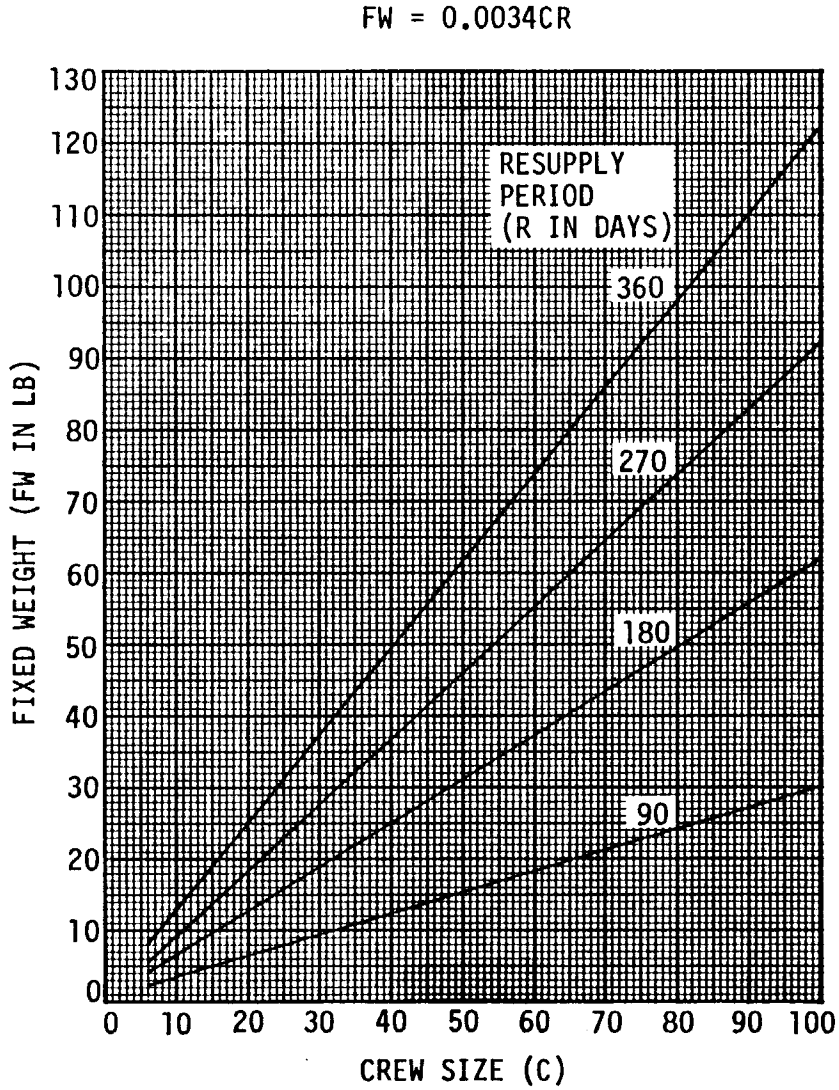


Figure 3-60. Disposable Vomitus Collector Fixed Weight

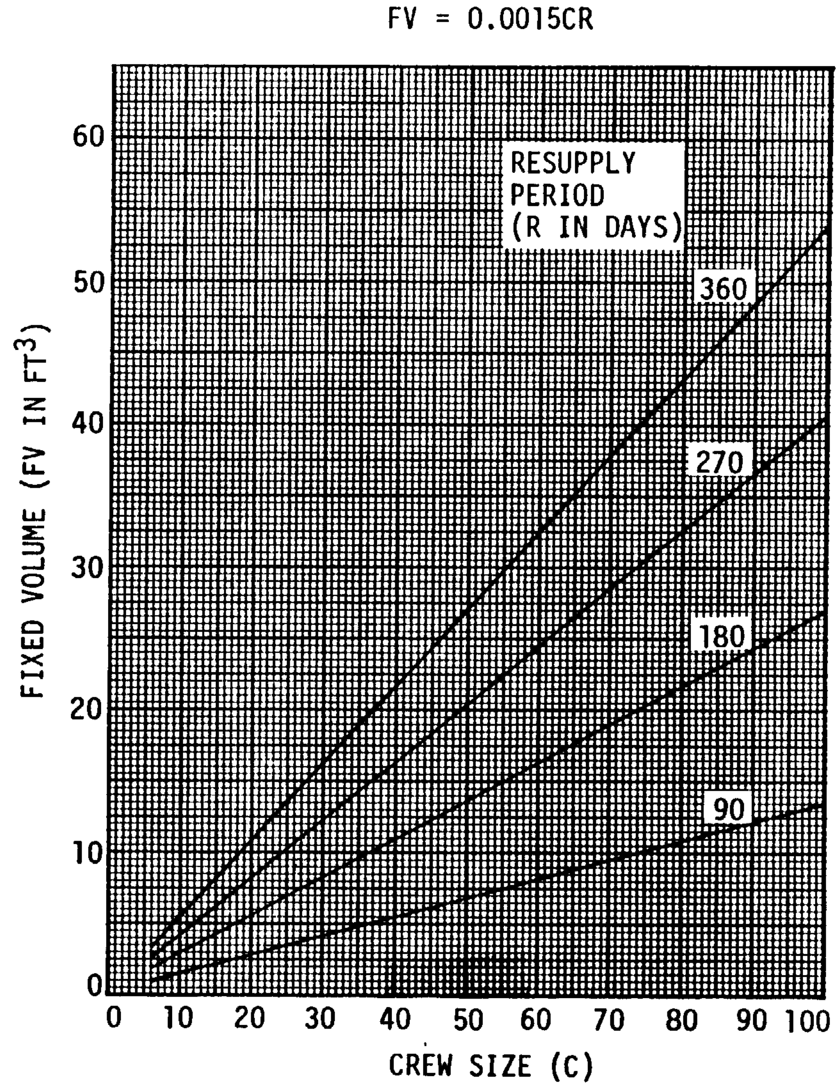


Figure 3-61. Disposable Vomitus Collector Fixed Volume

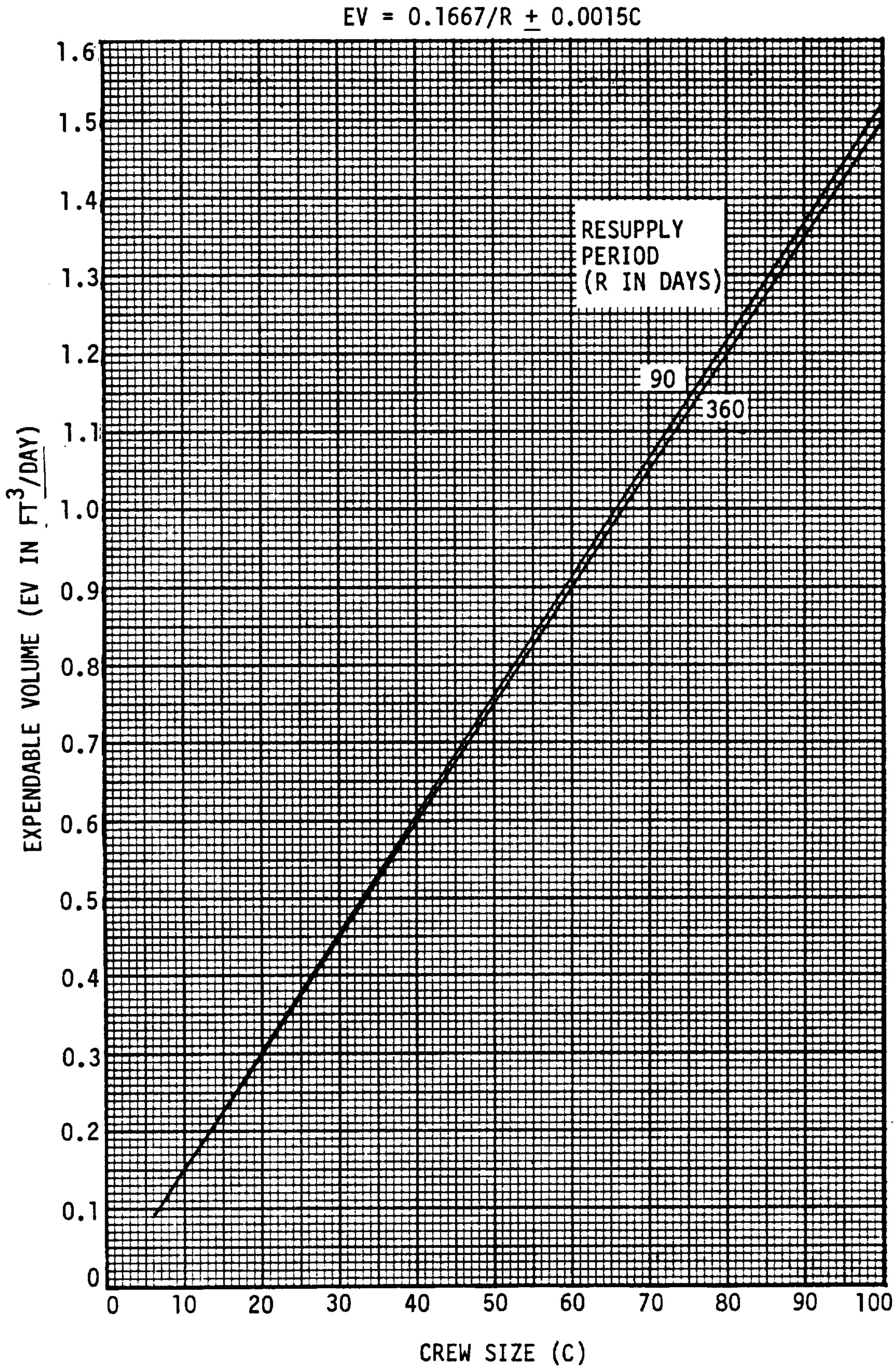


Figure 3-62. Disposable Vomitus Collector Expendable Volume

Disposable Lining Collector (Figure 3-59)

This collector functions the same as the disposable collector but has a plastic liner on the inside and upper surface. The reusable adaptor is made of metal with provision for attachment of the liner. Liners are disposed of into the feces collection unit after use.

Disposable Lining Collector Engineering Data

Fixed Weight (FW in lb)			Figure 3-63
Adaptors		0.25N	
Dispensers (from Appendix A)	$1.152FV_D$	0.000825CR	
	Total FW =	0.25N+0.000825CR	
Fixed Volume (FV in ft^3)			Figure 3-64
Adaptors		0.1667N	
Dispensers		0.000715CR	
	Total FV =	0.1667N+0.000715CR	

Expendable Weight (EW in lb/day)
Liners
EW = 0.0043C

Expendable Volume (EV in ft^3/day)
Liners
EV = 0.000715C

$$FW = 0.25N + 0.000825CR$$

$$FW = \text{Factor A} + \text{Factor B}$$

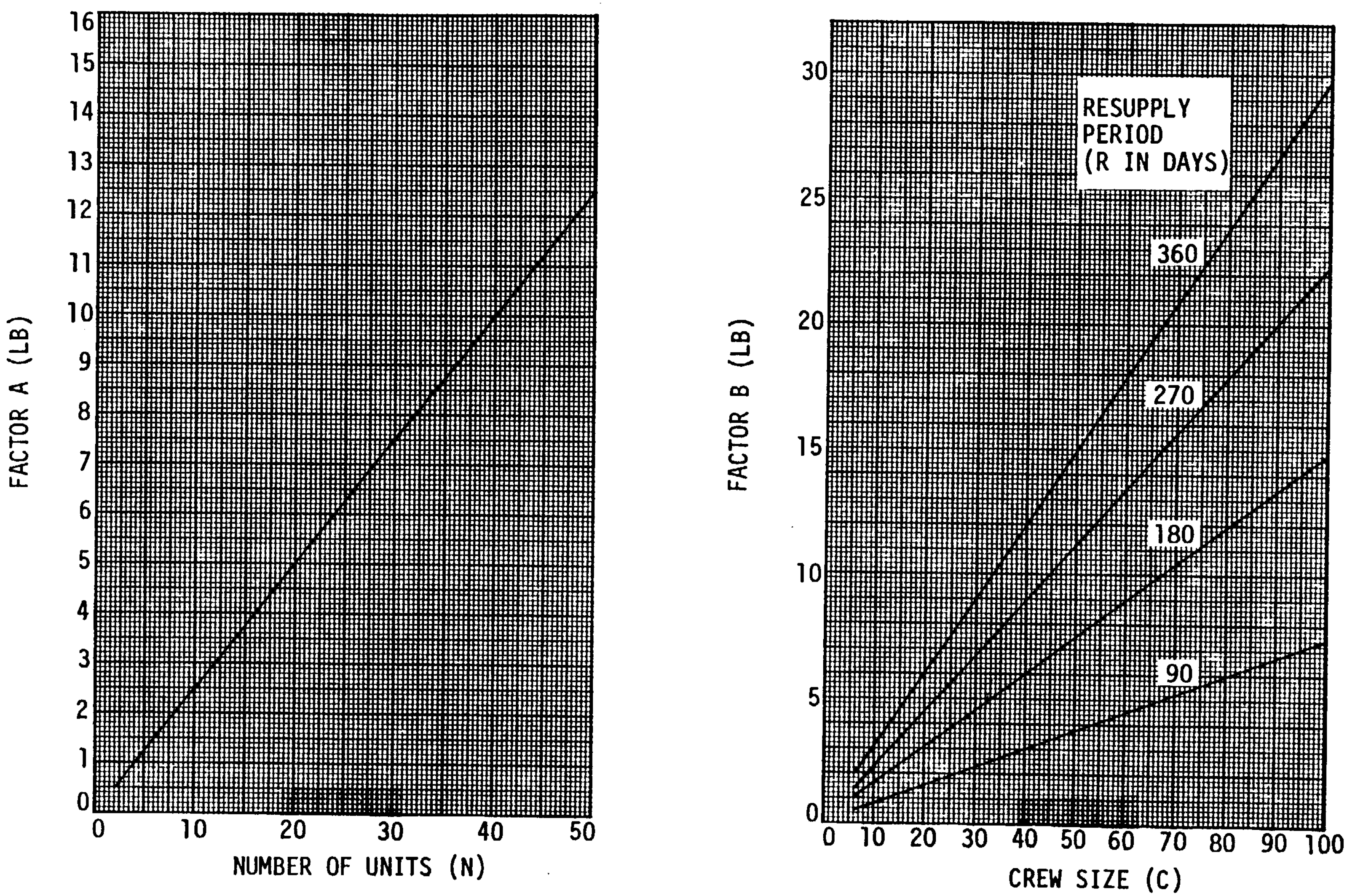


Figure 3-63. Disposable Lining Vomitus Collector Fixed Weight

$$FV = 0.1667N + 0.000715CR$$
$$FV = \text{Factor A} + \text{Factor B}$$

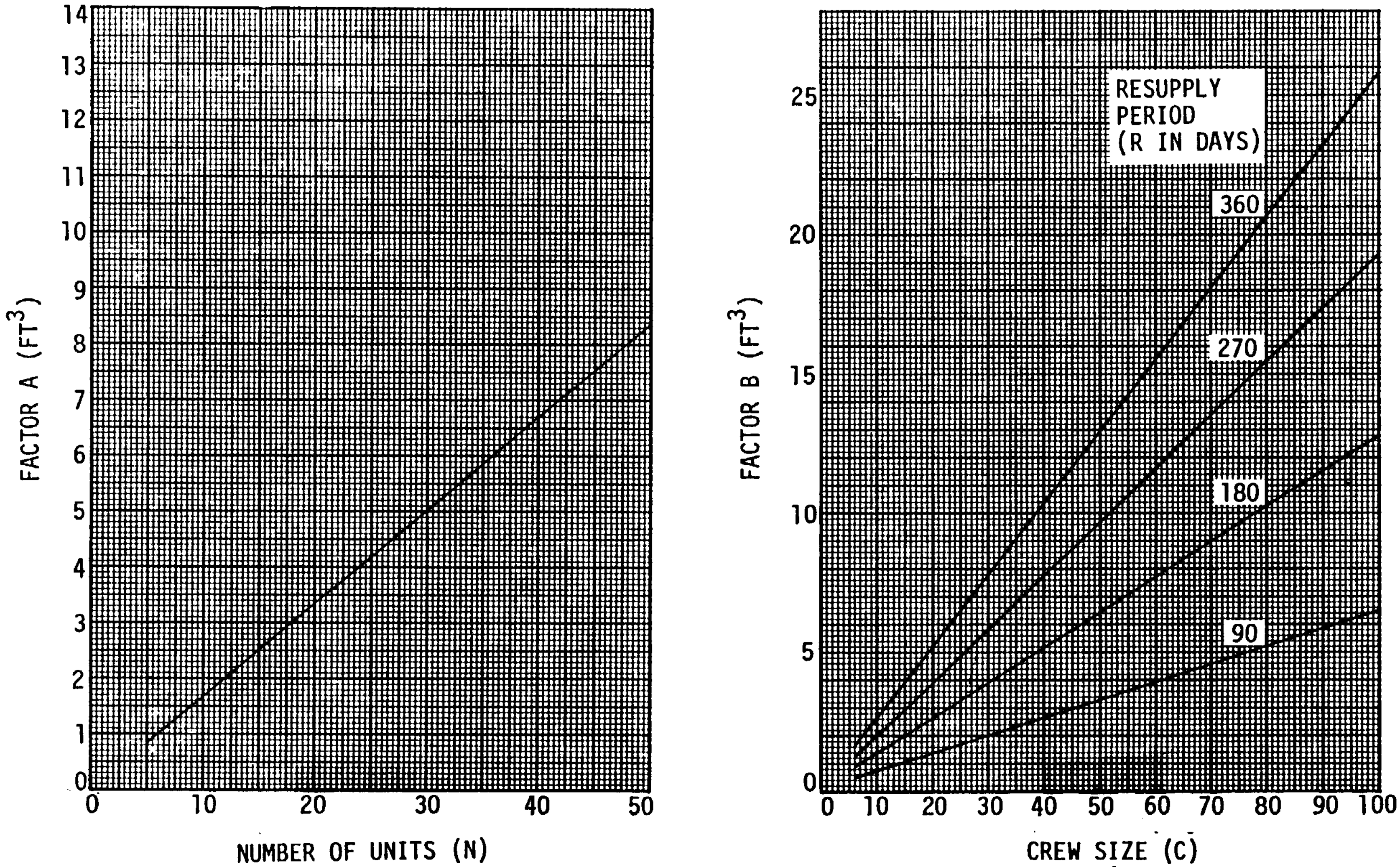


Figure 3-64. Disposable Lining Vomitus Collector Fixed Volume

4.0 PERSONAL CARE AND GROOMING

4.1 WHOLE BODY CLEANING

4.1.1 Assumptions.

- It is assumed that whole body washing will be accomplished at a minimum of once per week.
- It is assumed that hands will be washed at a minimum after urinating, after defecating, and before each meal.
- It is assumed that the face will be washed a minimum of twice per day and after strenuous work.
- It is assumed that crotch and armpits will be washed once per day.

4.1.2 Requirements.

- Water used for cleaning shall not contain viable bacteria.
- Cleansing agents shall allow maintenance of the normal balance of microbial flora.
- Cleansing agents shall not sensitize the skin to ultra-violet and ionizing radiations.
- Cleansing agents, in all their states, shall be non-toxic, non-volatile, non-flammable, non-explosive, and non-irritating.
- Cleansing agents and methods (e.g., scrubbing) should provide effective cleaning by removing desquamated keratin scales of the epidermis, body-odor producing substances, and external contaminants, but shall allow an adequate level of sebum to be maintained.
- Cleansing agents should not produce deposits or films on the body.

4.1.3 Concept Descriptions and Engineering Data. The whole body cleaning concepts discussed in this section are: a) Shower with Fixed Nozzles, b) the Hand-Held Scrubber, c) the Whole-Body Shower - Concept 1, and d) the Whole-Body Shower - Concept 2.

Shower with Fixed Nozzles (Figure 4-1)

A shower stall, approximately 30 inches in diameter and 7 feet high, is equipped with a ring of spray nozzles located around the upper edge of the cylinder. Accurate and automatic control of water temperature is provided to eliminate the use of water for manual temperature adjustment purposes. Control is accomplished by a temperature control valve which mixes hot water with cold water from an accumulator. A fan creates a high volume flow of air (approximately 1,000 cfm) to direct free water droplets in zero g. Air enters the top of the stall, picks up water, and exits at the bottom. The fan motor is used to heat the air to increase crew comfort. A motor-driven centrifugal separator separates the free water from the air stream. The water is processed to the water management system and the air is recirculated through the shower. A bleed valve at the fan inlet and an exhaust port at the separator outlet bleed in fresh air to control the carbon dioxide level.

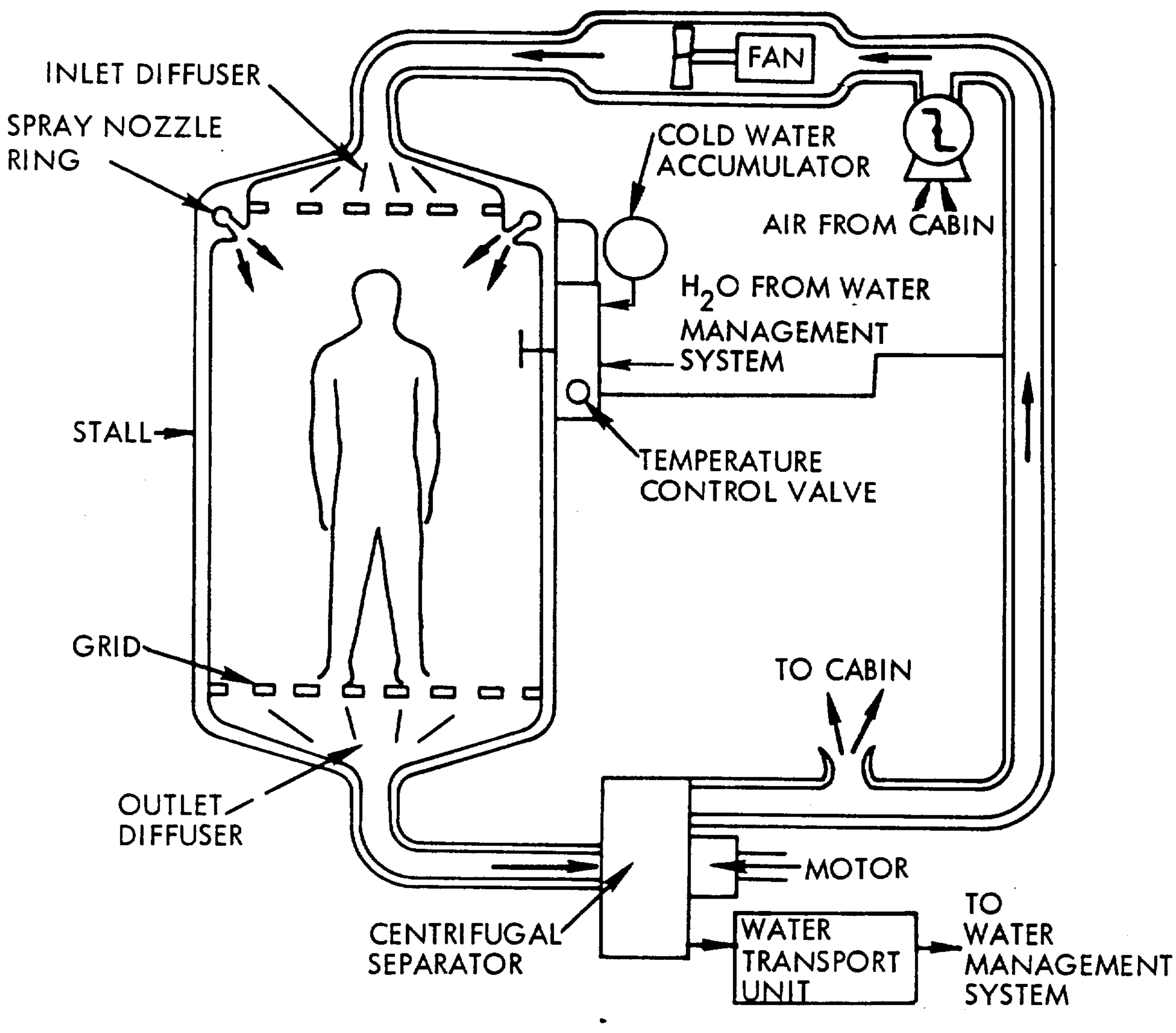


Figure 4-1. Shower with Fixed Nozzles

Shower with Fixed Nozzles Engineering Data

Fixed Weight (FW in lb)			Figure 4-2
Stall unit			
Shell	42.3N		
Diffusers	3.5N		
Grid	2.0N		
Nozzle ring	1.5N		
		49.3N	
Temperature control			
Valves	3.0N		
Heat exchanger	4.0N		
Accumulator	4.3N		
		11.3N	
Air transport unit			
Fan	13.5N		
Separator	15.0N		
Bleed valve	1.6N		
		30.1N	
Water transport unit			
Pump	2.9		
Filter	1.9		
		4.8N	
Ducting (See Appendix A)		$28N/P^{0.25}$	
	Total FW =	$(95.5+28/P^{0.25})N$	
Fixed Volume (FV in ft^3)			
Stall and duct unit		44.0N	
Temperature control		1.1N	
Air transport unit		2.2N	
Water transport unit		0.5N	
	Total FV =	47.8N	
Power, Maximum (PM in watts)			Figure 4-3
Fan (See Appendix A)		$2230.0/P^{0.5}$	
Separator		80.0	
Pump		5.0	
	Total PM =	$85.0+2230.0/P^{0.5}$	

Power, Average (PA in watt-hours/day) Figure 4-4

PA = hours use per man-day (PM)C

$PA = (0.044 \text{ hours per man-day})(85+2230.0/P^{0.5})C$

$PA = (3.74+99.0/P^{0.5})C$

Water Influx from WMS (WI in lb/day)

WI = Water weight per shower (C/3 showers per day)

$WI = 20.0\ (C/3)$

$WI = 6.667C$

Water Vapor rejected to atmosphere (WV in lb/day)

$WV = 0.33C$ (purge flow+stall volume) vapor added/ft^3

Find total purge flow based on allowable carbon dioxide

Assume: A) Ambient carbon dioxide partial pressure = 2.0 mmHg
B) Carbon dioxide partial pressure in shower = 3.5 mmHg
C) Carbon dioxide production rate = 0.00147 lb/minute
D) Carbon dioxide density = 0.11 lb/ft^3

A mass balance on the shower shows that:

CO_2 effluent = CO_2 influx + CO_2 from man

0.11 (purge rate) 3.5/760 = 0.11 (purge rate)(2.0/760)+0.00147

So: Purge rate = 6.8 CFM
Total purge flow = (time/shower)purge rate
Total purge flow = (8.0 minute/shower) 6.8 CFM
Total purge flow = 54.4 ft^3

Find vapor added per ft^3

Assume: A) Ambient temperature = 70°F
B) Shower temperature = 90°F
C) Ambient R.H. = 50.0%
D) Shower R.H. =100.0%

At 90°F and 100.0% R.H. $M_V/M_A = 0.03$

At 70°F and 50.0% R.H., $M_V/M_A = 0.008$

Vapor added/ft^3 = (0.075 lb air/ft^3)(0.03-0.008)lb water/lb air

Vapor added/ft^3 = 0.00165 lb water/ft^3

$WV = 0.33C$ (purge flow+stall volume)(vapor added/ft^3)

$WV = 0.33C\,(54.4+44.0)(0.00165)$

$\underline{WV = 0.0514C}$

Water Effluent to WMS (WE in lb/day)

$WE = WI - WV$

$WE = 6.667C - 0.0514C$

$\underline{WE = 6.616C}$

Cooling from liquid loop, Average (Q_{LA} in Btu/day)

Reduction of water temperature from 160 to 100°F

$Q_{LA} = C_p\,(T_1 - T_2)\,WI$

$Q_{LA} = 1.0\,(160-100)\,6.667C$

$\underline{Q_{LA} = 400C}$

Cooling from liquid loop, Peak (Q_{LP} in Btu/minute)

$Q_{LP} = Q_{LA}$/cooling time per day

$Q_{LP} = 400C$ Btu per day/3.33C minutes per day

$\underline{Q_{LP} = 120C}$

Cooling from atmosphere, average (Q_{CA} in Btu/day)	Figure 4-4

Q_{CA} = minutes per man-day$(PM_F)C$

$Q_{CA} = 2.667\ (2230.0/P^{0.5})C$

$Q_{CA} = 5940.0C/P^{0.5}$ watt minute/day

$\underline{Q_{CA} = 338.0C/P^{0.5}}$

Initial and resupply period spares weight (SI and SR in lb)	Figures 4-5 and 4-6

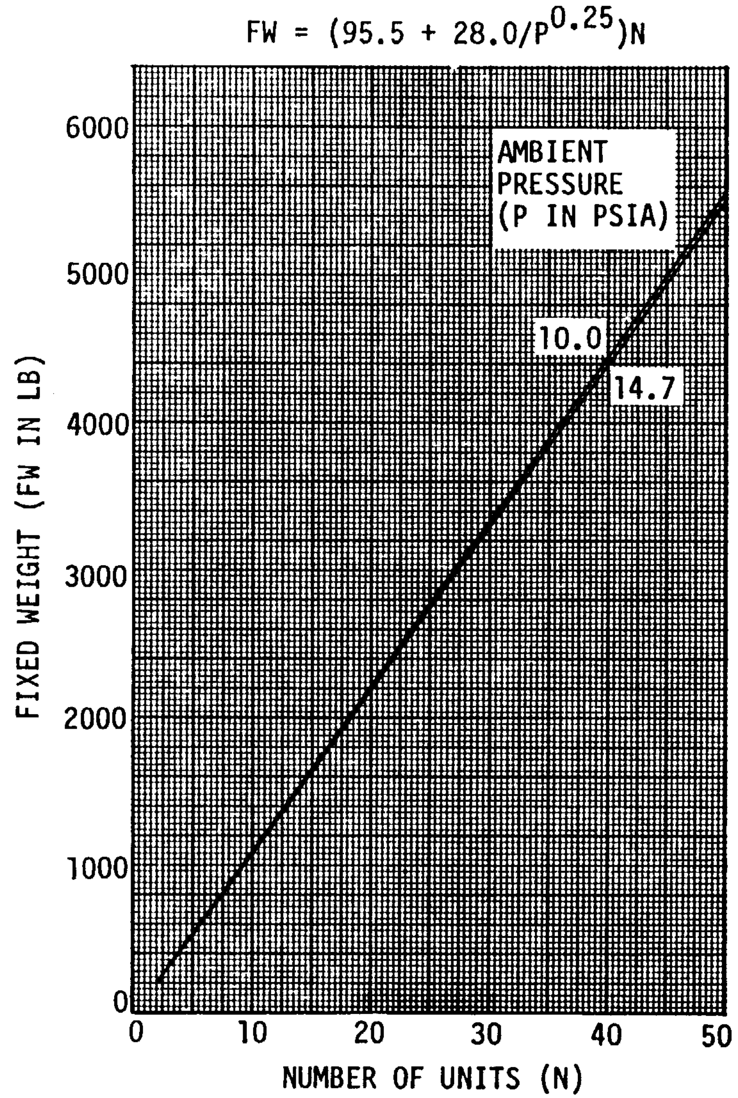


Figure 4-2. Shower with Fixed Nozzles Fixed Weight

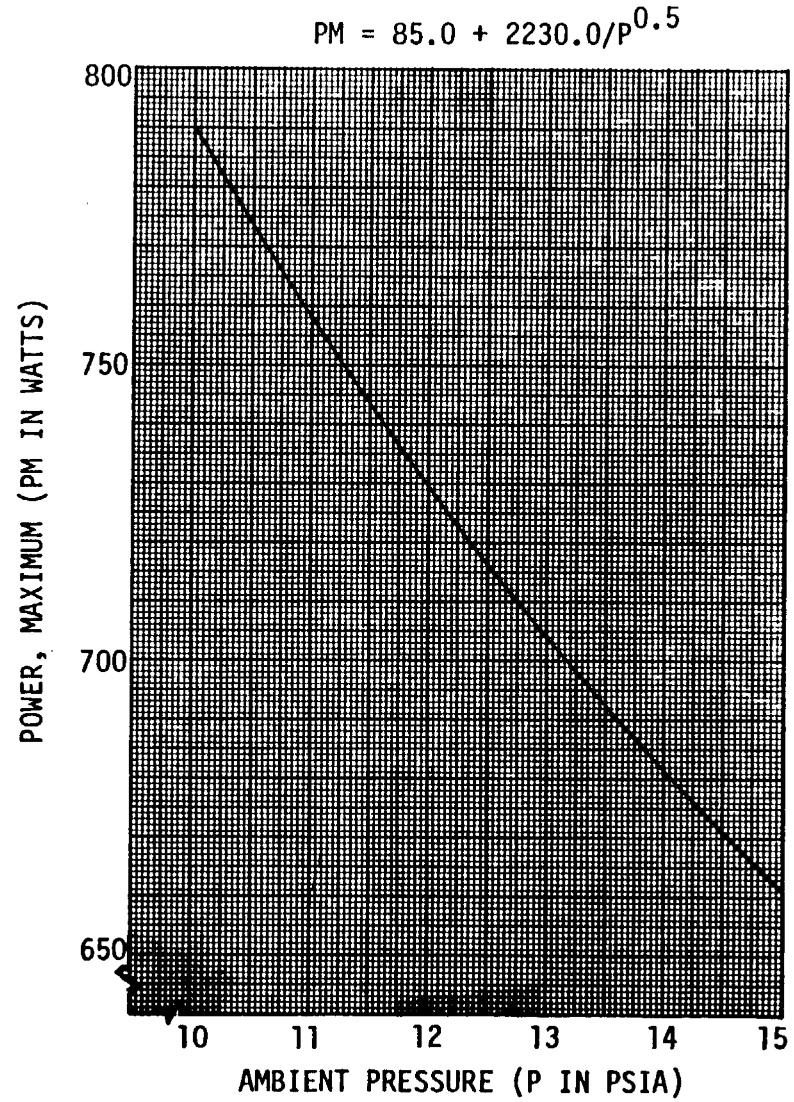


Figure 4-3. Shower with Fixed Nozzles Power, Maximum

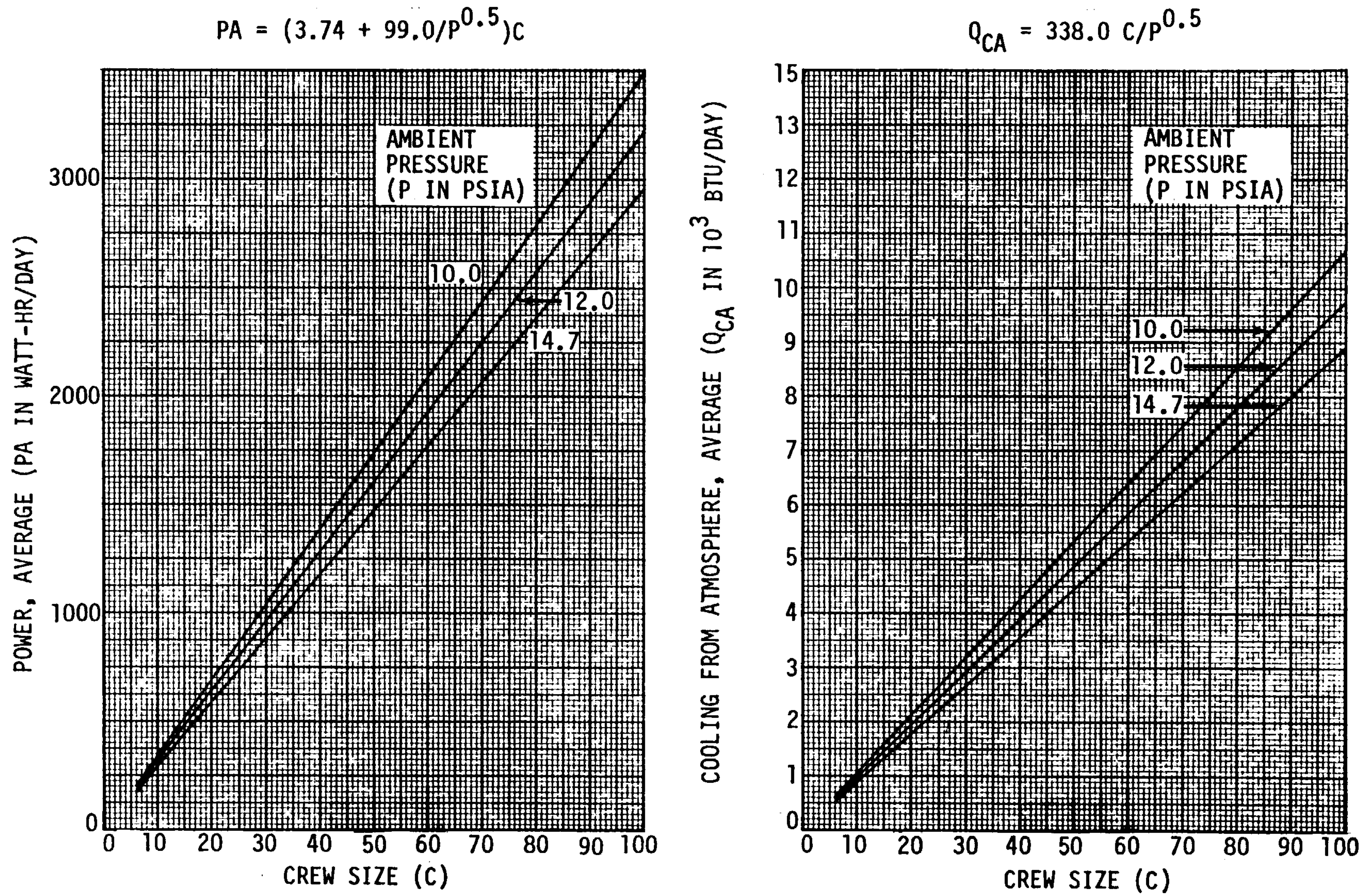


Figure 4-4. Shower with Fixed Nozzles Average Power and Cooling from Atmosphere

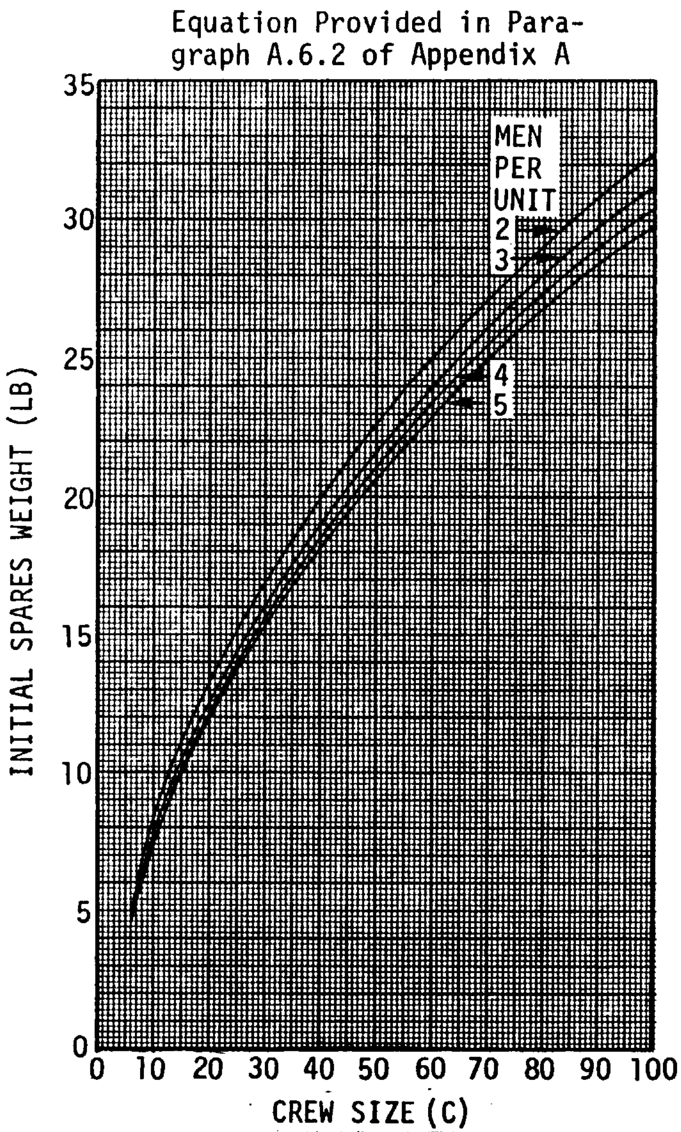


Figure 4-5. Shower with Fixed Nozzles Initial Spares Weight

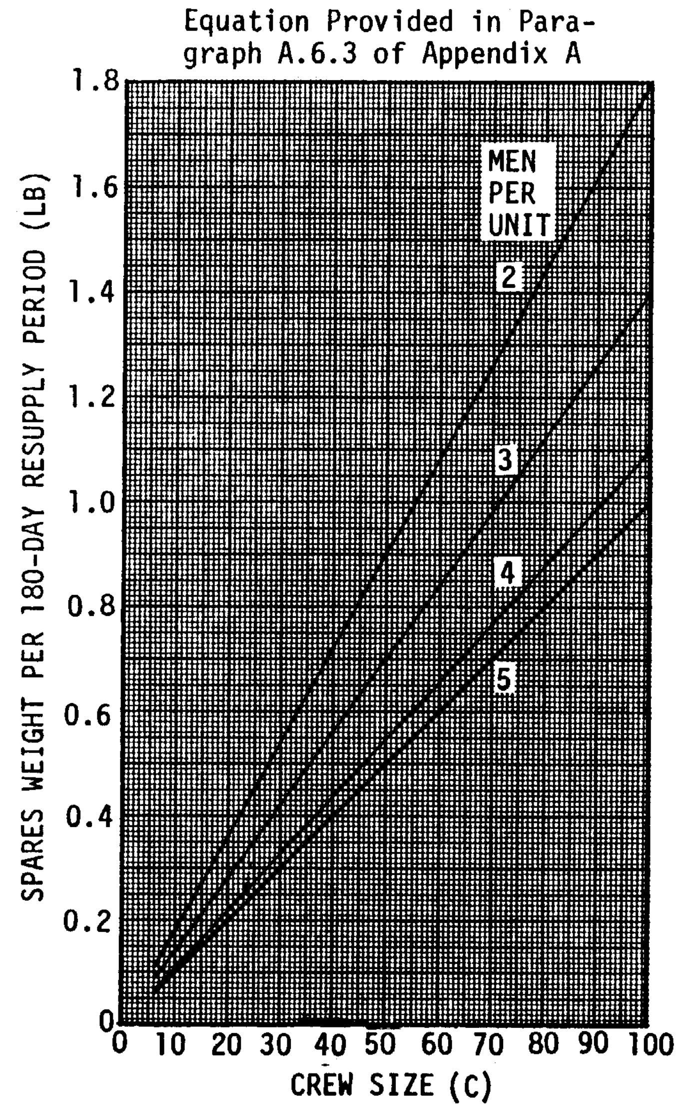


Figure 4-6. Shower with Fixed Nozzles Resupply Period Spares Weight

Hand-Held Scrubber (Figure 4-7)

The hand-held scrubber head is connected by coaxial flex tubing to a water supply valve and a centrifugal separator. The water valve controls input water to the sponge in the scrubber head. A water pick-up housing connected to the vacuum line surrounds the sponge. Free water is transferred through the pick-up housing to the centrifugal separator. After the air and water are separated, a pump unit injects the water into the water management system and the air transport system returns the processed air to the cabin.

Hand-Held Scrubber Engineering Data

Fixed Weight (FW in lb)

Fan	1.6N
Separator	4.0N
Filter	2.0N
Hose	1.5N
Scrubber	0.5N
Pump unit	5.0N
Water supply unit	6.0N
Total FW =	20.6N

Fixed Volume (FV in ft^3)

Head and hose	0.5N
Support unit	1.0N
Total FV =	1.5N

Expendable Weight (EW in lb/day)

Sponges (0.03 lb each)

EW = 0.03 (use rate)C

EW = 0.03 (1.0/30 man-days)C

EW = 0.001C

Expendable Volume (EV in ft^3/day)

Sponges (0.0049 ft^3 per man month)

EV = 0.00016C

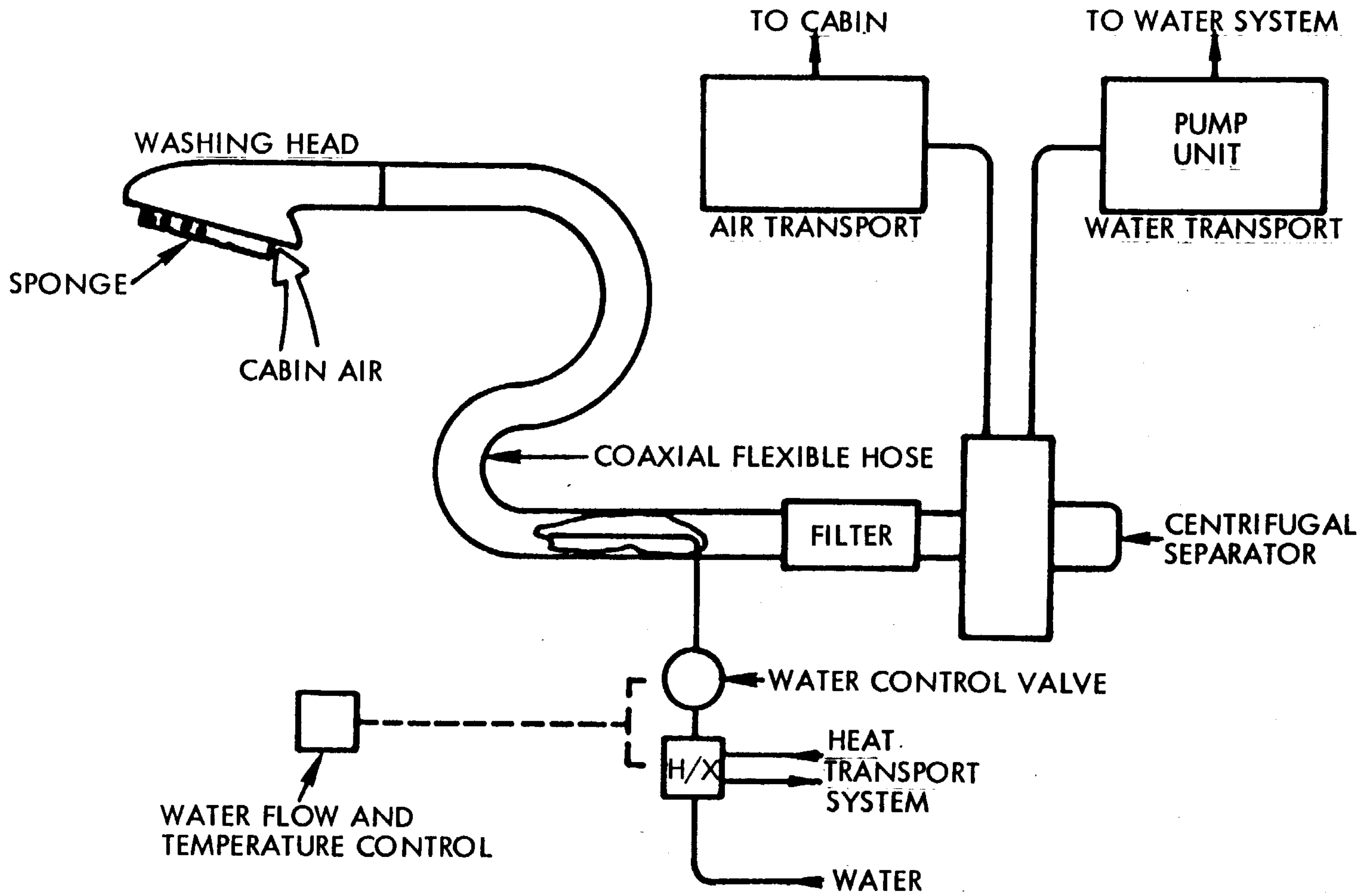


Figure 4-7. Hand-Held Scrubber

Power, Maximum, (PM in watts) Figure 4-8

Fan (See Appendix A)	$20.4/P^{0.5}$
Separator	30.0
Pump	5.0
Total PM =	$35.0+20.4/P^{0.5}$

Power, Average (PA in watt-hours/day) Figure 4-9

PA = (PM)hour used per day

$PA = (35.0+20.41P^{0.5})0.1C$

$PA = (3.5+2.04/P^{0.5})C$

Water Influx from WMS (WI in lb/day)

WI = (0.5C uses per day)(1.0 lb per use)

WI = 0.5C lb/day

Water Vapor rejected to atmosphere (WV in lb/day)

$WI\ (T_1-T_2)c_p = h_{fg}\ WV$ (Note: h_{fg} = latent heat of vaporization of H_2O)

0.5C (100-70) 1.0 = 1100.0 WV

WV = 0.014C

Water Effluent to WMS (WE in lb/day)

WE = WI - WV

WE = 0.5C - 0.014C

WE = 0.486C lb/day

Cooling from liquid loop, Peak (Q_{LP} in Btu/minute).

$Q_{LP} = Q_{LA}$/cooling time per day

$Q_{LP} = 30.0C/5.0C$

$Q_{LP} = 6.0C$

Cooling from liquid loop, Average (Q_{LA} in Btu/day)

Cool water from 160 to 100°F

$Q_{LA} = c_p(T_1-T_2)WI = 1.0(160-100)0.5C$

$Q_{LA} = 30.0C$

Cooling from atmosphere, Peak (Q_{CP} in Btu/minute)

$Q_{CP} = (PM_F)\ 0.034$ (NOTE: PM_F = power of fan in watts)

$Q_{CP} = (20.4/P^{0.5})0.034$

$Q_{CP} = 0.7/P^{0.5}$

Cooling from atmosphere, Average (Q_{CA} in Btu/day) Figure 4-10

Q_{CA} = minutes use per day (Q_{CP})

$Q_{CA} = 6.0C\ (0.7/P^{0.5})$

$\underline{Q_{CA} = (4.2/P^{0.5})C}$

Laundry load (wash in lb/day)

WASH = (lb/sponge)sponges per day

WASH = (0.03)C/2

$\underline{\text{WASH} = 0.015C}$

Initial and resupply period spares weight (SI and SR in lb) Figures 4-11 and 4-12

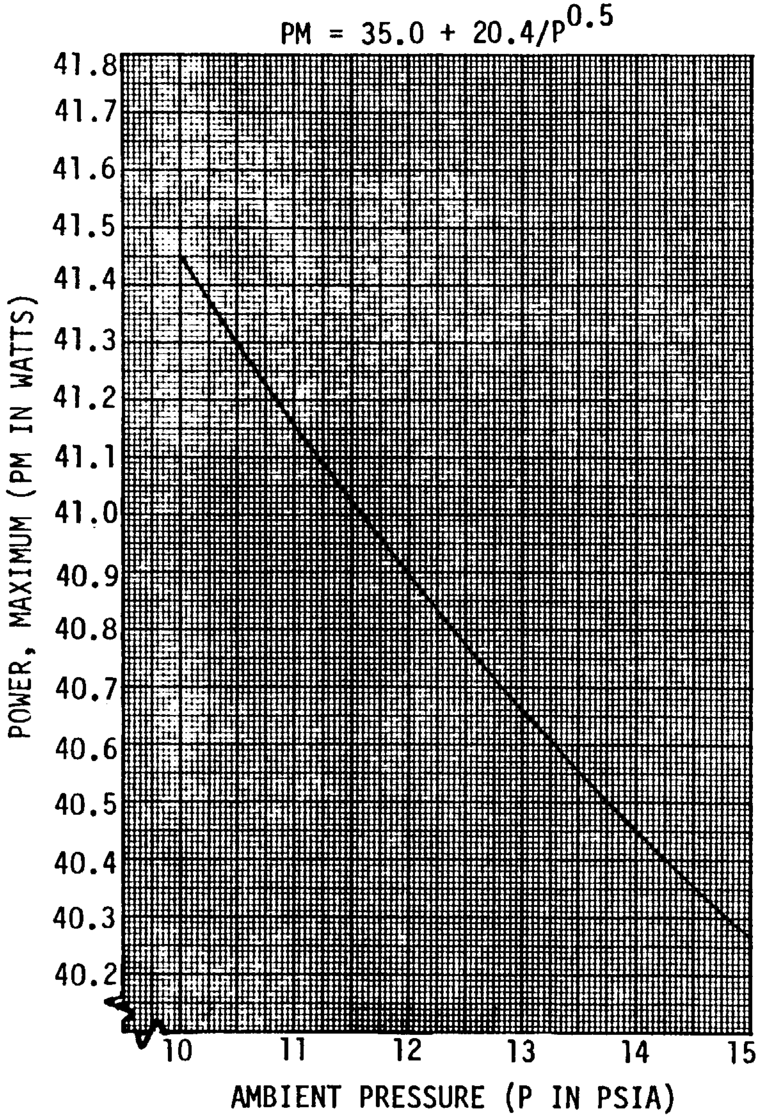


Figure 4-8. Hand-Held Scrubber Power, Maximum

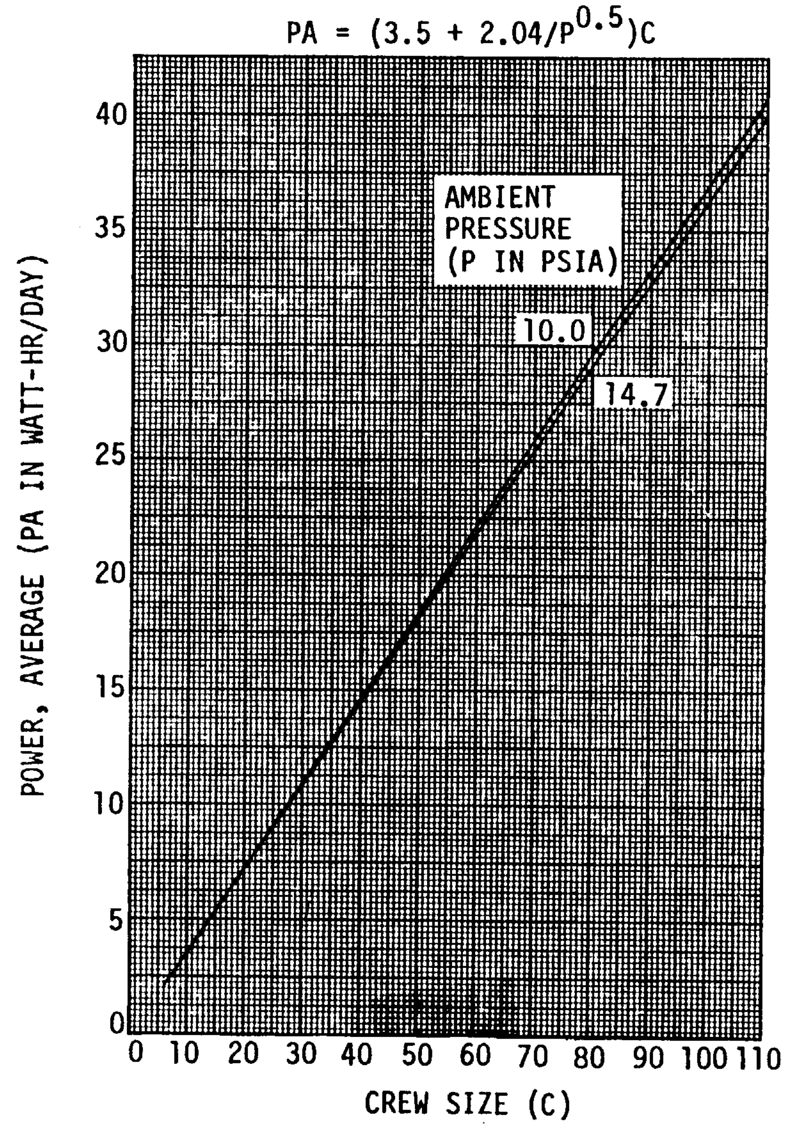


Figure 4-9. Hand-Held Scrubber Power, Average

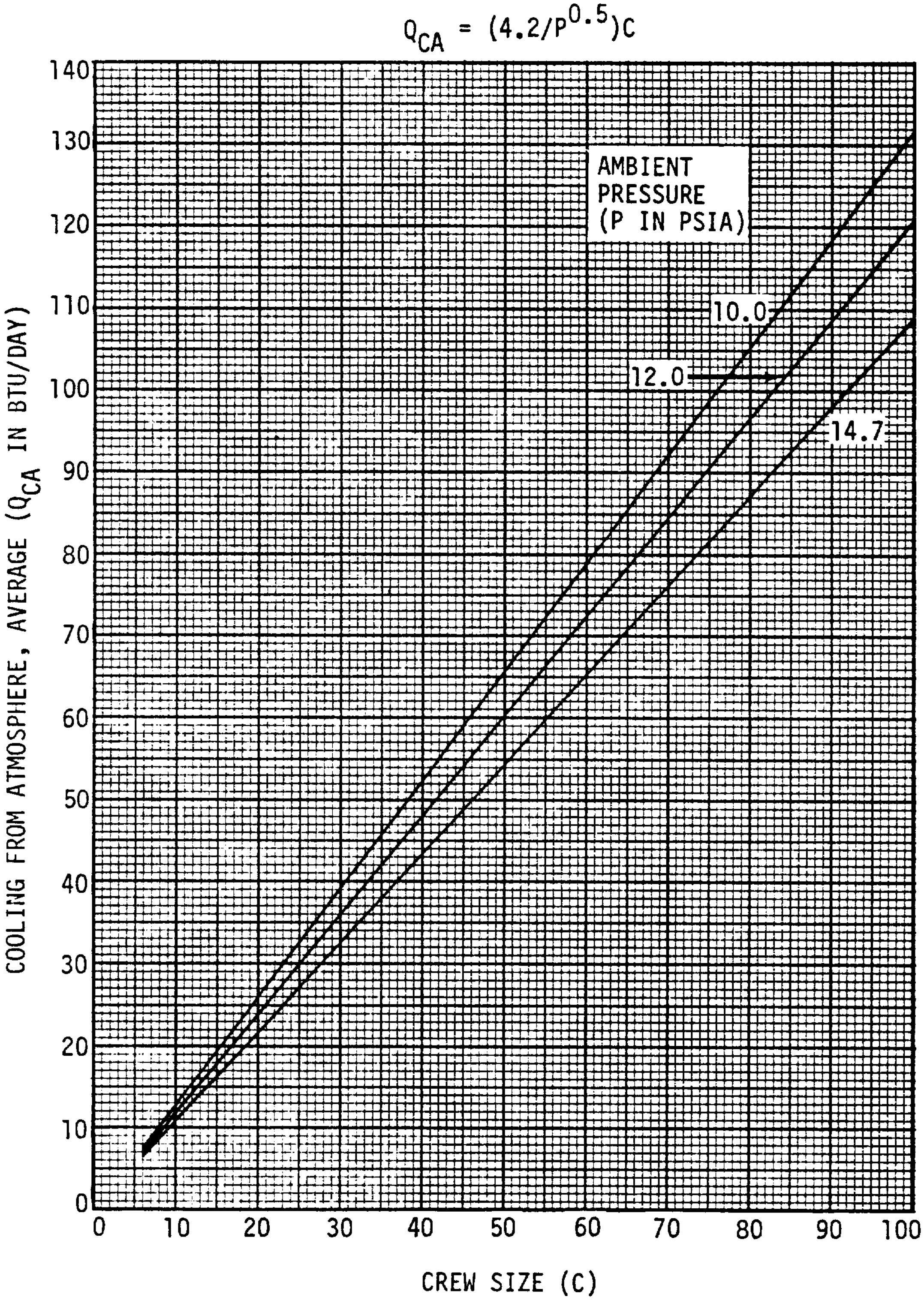


Figure 4-10. Hand-Held Scrubber Cooling from Atmosphere, Average

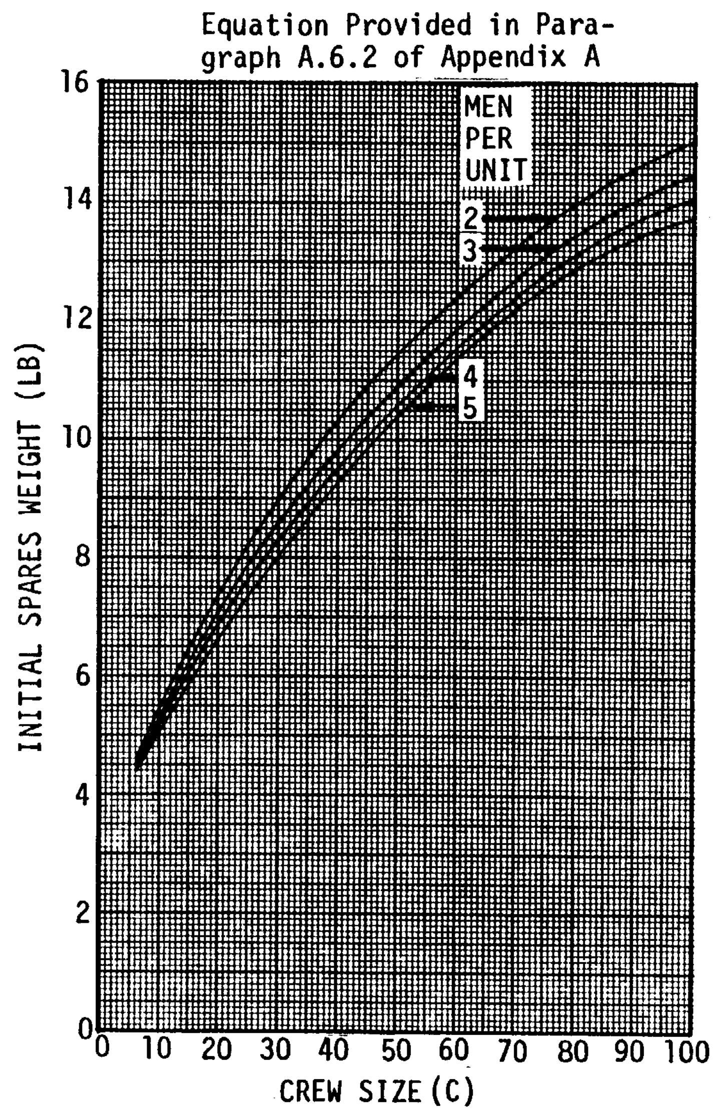


Figure 4-11. Hand-Held Scrubber Initial Spares Weight

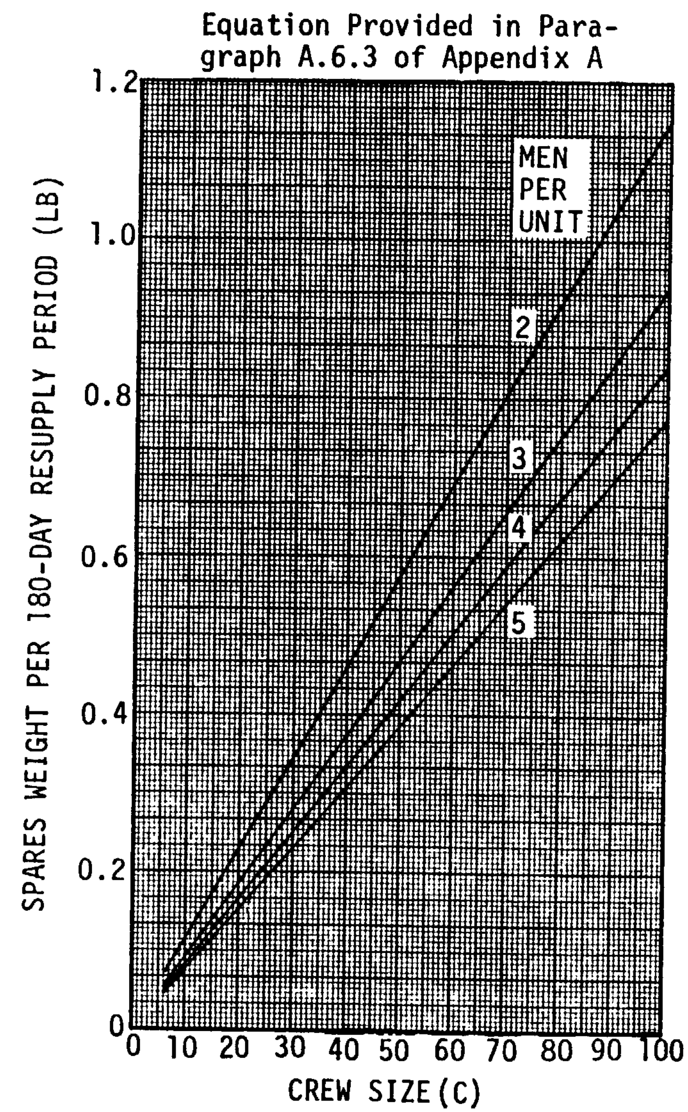


Figure 4-12. Hand-Held Scrubber Resupply Period Spares Weight

Whole-Body Shower - Concept 1* (Figure 4-13)

This subassembly consists of the primary shower enclosure with functional support equipment as follows:

- An air flow loop which controls CO_2 buildup, air temperature, and humidity and water movement
- A water supply system which contains fresh and waste water tanks and associated valving and controls
- A water collection system which uses an air drag method to control free water and consists of a two-phase inlet duct, a vortex liquid-gas separator, a water pump and controls.

Two candidate shower stall configurations are shown in Figure 4-14. The restraints used in each configuration are similar; elastic-band foot holds are provided on the floor and hand holds are located on the upper portion of the stalls.

The triangular tapered prism uses a straight vertical air flow pattern from top to bottom. The air enters a plenum on top of the shower and passes through a perforated baffle plate to achieve the vertical flow. The round tapered stall allows the larger volume for washing movements, but as a result, a vertical air flow pattern will not attain the desired velocity. Therefore, the air is introduced tangentially at the top of the shower to form a vortex flow pattern and concentrate the bulk of the air flow at the walls.

The hand-held movable spray nozzle provides water for the wetting and rinsing operations. The most suitable spray pattern determined during nozzle parameter investigation was a 25-degree solid cone with a flow rate of 0.35 gpm at 20 psig. The optimum water temperature for cleansing and crewman comfort is 105°F. The water quantity required for one complete shower, excluding shower stall cleanup, is 0.58 gallon.

The air circulation is provided by an axivane van (rated at 1200 cfm at 13 inches of water) whose output is damped to provide a flow rate of 200 cfm and heated to 105($\pm$5)°F for crew comfort. The air passes through the shower stall and out the two-phase duct. The air drags the free water

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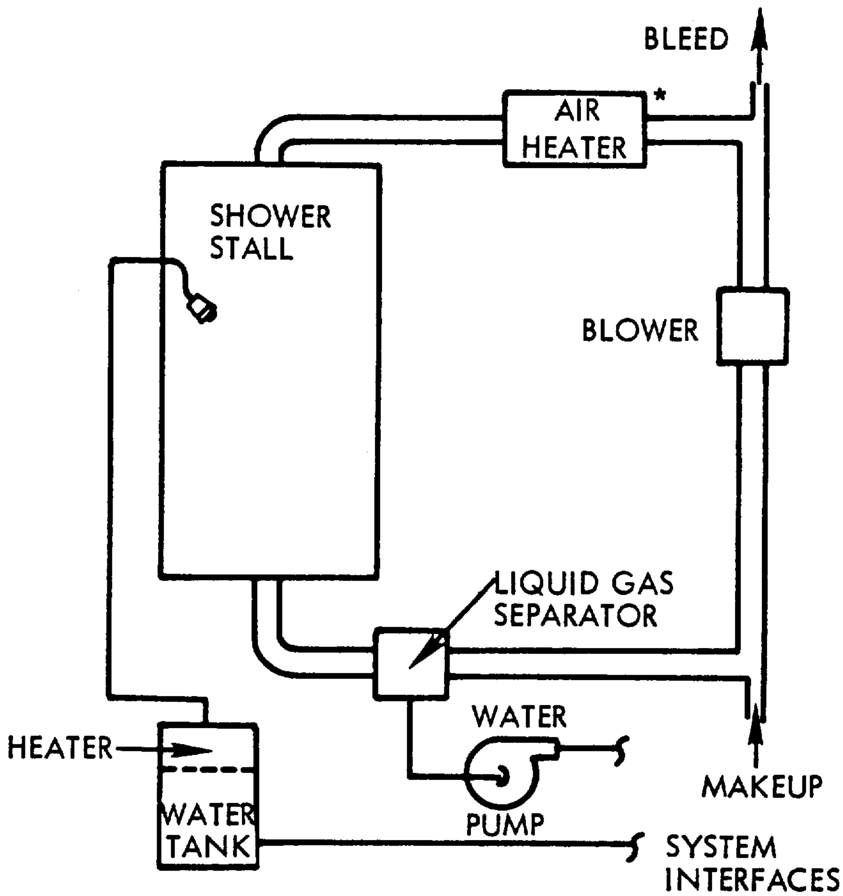
*Data extracted from Reference 4

through the two-phase duct into the water liquid-gas separator, and provides the force in the vortex to separate the water from the air. The shower outlet air is then mixed with ambient air and recirculated through the fan.

Using the circulating air flow (air drag) for water collection requires the use of a manually operated water scraper to move water accumulated on the shower walls toward the air duct. The outlet ducting is sized to achieve the 40 fps air velocity necessary to drag water along the duct surfaces into the liquid-gas separator.



* OPTIONAL

AIRFLOW: 200 CFM
SYSTEM STATIC: 4 INCHES OF H_2O
DRYING: TOWEL ONLY
OPERATION TIME: 10 MINUTES MAXIMUM
CLOSED LOOP WITH 10 CFM BLEED

Figure 4-13. Whole-Body Shower - Concept 1

Whole Body Shower (Concept 1) Engineering Data

Fixed Volume - Stall (FV in ft^3) Figure 4-14

Power, Average (PA in watt-hours/day)

PA = (36 watt-hours/shower)(number of showers/day)

Fan Capacity (FC in cfm)

FC = 1200 cfm

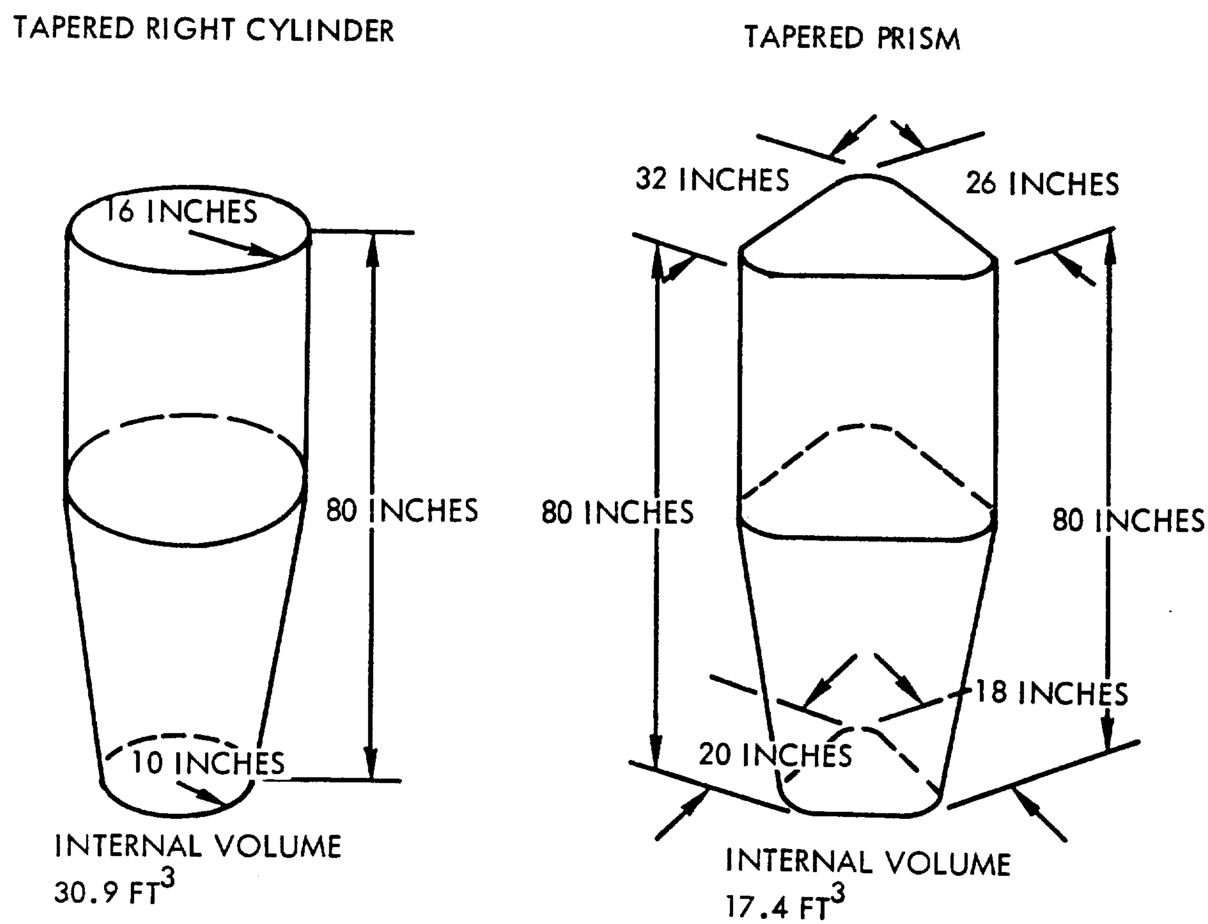


Figure 4-14. Shower Stall Volume

Whole-Body Shower - Concept 2 (Figure 4-15)

This subassembly consists of the primary shower enclosure with functional support equipment as follows:

- A recirculating gas loop, which provides CO_2 removal and oxygen supply within the enclosure, directs the water stream flow, removes particles and bacteria from the gas stream, controls the enclosure temperature, and removes free water particles.
- A water supply and an inlet water temperature control
- A used water recirculating loop for extended shower use, including recovery of the water from the gas outflow stream
- Final humidity and particle processing of the gas dump to prevent cabin atmosphere overloads and/or contamination
- Provisions to return used water to the reclamation system
- A manually operated squeegee ring for wiping the interior stall walls after a shower.

Approximately one-half of the total water is used for washing and the remainder for rinsing. A manual temperature control valve is used to control the water inlet temperature by adjusting the coolant bypass ratio to the inlet water heat exchanger. Temperature and CO_2 are controlled in the shower by bleeding in cabin air (a valve at the circulating fan inlet opens to admit cabin air, automatically controlling temperature of the circulating air). Continuous water flow is controlled by a lever. The spray nozzle is attached to a flexible hose and may either be hand-held or positioned at any one of several locations on the wall of the enclosure.

The shower uses 16.6 pounds of water each time it is operated. Half of this quantity is used during initial temperature adjustment and body wetting prior to soaping. Next, an integrating flowmeter actuates a valve that causes this water to recirculate to enable the crewman to shower for as long as he wishes with the initial water quantity (approximately eight pounds). During this period of operation, the 1100 cfm air stream passes through the shower enclosure with a superficial velocity of 230 feet per minute, moving the free water out through the bottom of the enclosure. After passing through a rough filter, the air-water mixture enters a static water concentrator and air divider, where the water is concentrated into a smaller air stream by a direction reversal. The recirculating air is then combined with an inflow of cabin air to maintain constant air

*Data extracted from Reference 5

temperature and provide oxygen makeup and CO_2 control. The fan directs the controlled temperature air back to the shower enclosure. The smaller air stream from the water concentrator enters a rotary separator, where the free moisture is removed. The resulting air stream is then dehumidified in a condenser-separator before entering the cabin atmosphere. Water collected in the rotary water separator is pumped back to the spray nozzle.

A rinse control lever diverts the circulating water from the pump to the waste water recovery system (instead of to the spray nozzle) and permits the balance of the fresh water allowance to flow through the spray nozzle. Thus, the crewman receives a final rinse with fresh water. Drying is performed with a towel. Air drying was not considered because of possible excessive drying time and unreasonable power usage.

Although the number of showers taken by each crewman is limited by the water processing equipment and tank sizes, the length of time a crewman can spend in the shower is essentially unlimited, because the used water can be recirculated indefinitely.

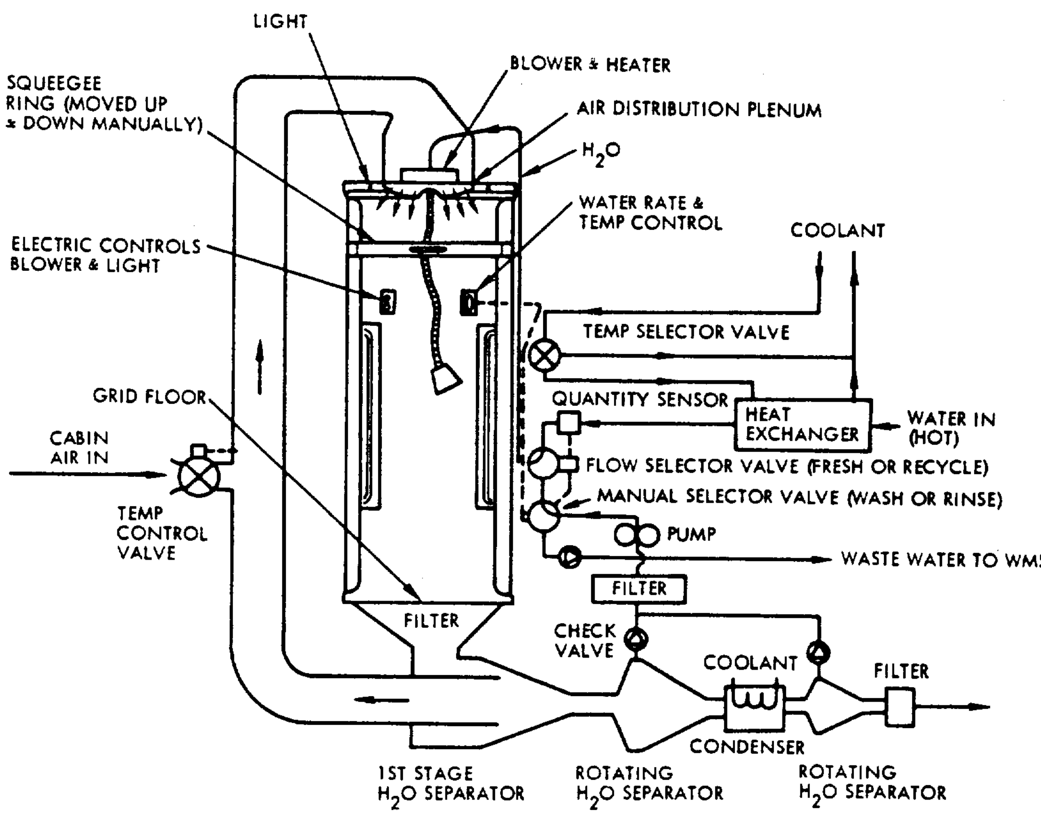


Figure 4-15. Whole-Body Shower (Concept 2)

Whole-Body Shower (Concept 2) Engineering Data

Fixed Weight (FW in lb)

FW = 332N

Fixed Volume* (FV in ft^3)

Stall	37.0N
Equipment	67.0N
Shelf	6.0N
	Total FV =110.0N

*Stall dimensions of 80-inch height and 32-inch diameter, air duct cross-section area of 200 in^2.

Power, Maximum (PM in watts)

PM = 500 watts

Power, Average (PA in watt-hours/day)

PA = (use time per day)(PM)

PA = 1.5 (500)

PA = 750 watt-hours/day

Fan Capacity (FC in cfm)

FC = 1100 cfm

Initial and resupply period spares (SI and SR in lb)

SI = 74 lb

SR (6 months) = 4 lb

Expendables

(6 water filters)(1-1/2 lb/filter) = 9 lb

4.2 LOCAL BODY CLEANING

4.2.1 Requirements. Refer to the requirements for "Whole Body Cleaning" (Paragraph 4.1.1).

4.2.2 Concept Descriptions and Engineering Data. The local body cleaning concepts contained in this section are: a) Reusable Wet Wipes, b) Disposable Wet Wipes, and c) Galley Wipes.

Reusable Wet Wipes (Figure 4-16)

A sponge bath technique, using wet wipes, can be used to clean local body areas (crotch, underarms, feet). The wipes are ten-inch squares of dry terry cloth, which are wetted before used. A mechanical wipe wetting system with an access hand hole is used to wet and soap the wet wipes. The wipe wetting system furnishes water and soap and has provisions for controlling the excess water with an air sweep through the hand hole. A centrifugal separator is provided to separate the free water from the air stream. Water temperature is controlled by mixing hot with cold water in a temperature-controlled mixing valve.

One wipe per man-day is used, after which it is laundered. After sixty washings, the wipe is discarded and replaced.

Reusable Wet Wipe Engineering Data

Fixed Weight (FW in lb)		Figure 4-17
Wetter unit		
Enclosure	8.0N	
Separator	4.0N	
Fan	3.3N	
Pump unit	5.0N	
Water supply unit	6.0N	
Ducting (See Appendix A)	$4.3N/P^{0.25}$	
	Total FW $=(26.3+4.3/P^{0.25})N$	

Fixed Volume (FV in ft^3)		Figure 4-17
Wetter unit		
Enclosure	2.25N	
Support units	1.25N	
	Total FV = 3.5N	

Expendable Weight (EW in lb/day)

Wipes

EW = (C wipes/60 days)(0.04 lb/wipe)

EW = 0.000667C

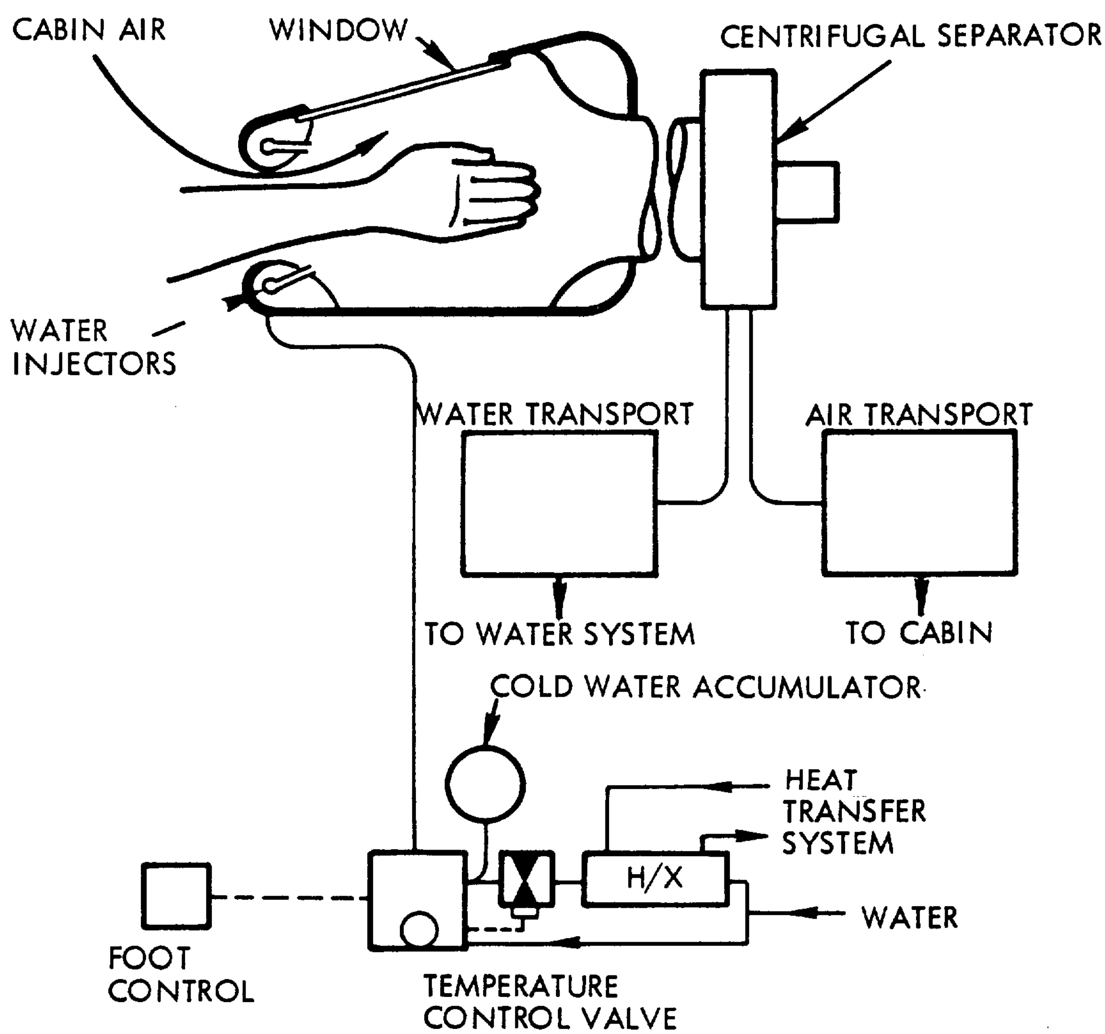


Figure 4-16. Wipe Wetting System

Expendable Volume (EV in ft^3/day)

Wipes

$EV = (C \text{ wipes}/60 \text{ days})(0.075 \text{ ft}^3/\text{wipe})$

$\underline{EV = 0.00125C}$

Power, Maximum (PM in watts) Figure 4-18

Separator	30.0
Pump	5.0
Fan (See Appendix A)	$533.0/P^{0.5}$
Total PM =	$35.0+533.0/P^{0.5}$

Power, Average (PA in watt-hours/day) Figure 4-19

PA =(time used per day)(PM)

$PA = 0.12C\ (35.0+533.0/P^{0.5})$

$\underline{PA = (4.2+64.0/P^{0.5})C}$

Water Influx from WMS (WI in lb/day)

WI = (5.0C uses/day)(1.0 lb/use)

$\underline{WI = 5.0C}$

Water Vapor rejected to atmosphere (WV in lb/day)

$h_{fg}\ WV = WI\ (T_1-T_2)c_p$ (Note: h_{fg} = latent heat of vaporization of H_2O)

1100.0 WV = (5.0C)(30)(1.0)

$\underline{WV = 0.14C}$

Water Effluent to WMS (WE in lb/day)

WE = WI -WV

WE = 5.0C-0.14C

$\underline{WE = 4.86C}$

Cooling from liquid loop, Peak (Q_{LP} in Btu/minute)

Cool water from 160 to 100°F

$Q_{LP} = c_p\ (T_1-T_2)$ 0.1 lb/minute

$Q_{LP} = 1.0\ (160-100)\ 0.1$

$\underline{Q_{LP} = 6.0 \text{ Btu/minute}}$

Cooling from liquid loop, Average (Q_{LA} in Btu/day)

$Q_{LA} = WI\ (T_1-T_2)c_p$

$Q_{LA} = 5.0C\ (160-100)\ 1.0$

$\underline{Q_{LA} = 300.0C}$

Cooling from atmosphere, Peak (Q_{CP} in Btu/minute) Figure 4-18

$$Q_{CP} = 0.034\ (PM_F)$$
$$Q_{CP} = 0.034\ (533.0/P^{0.5})$$
$$\underline{Q_{CP} = 18.1/P^{0.5}}$$

Cooling from atmosphere, Average (Q_{CA} in Btu/day) Figure 4-19

$$Q_{CA} = (Q_{CP})(\text{time per day})$$
$$Q_{CA} = (18.1/P^{0.5})(7.2C)$$
$$\underline{Q_{CA} = 130.0C/P^{0.5}}$$

Laundry Load (LL in lb/day)

$$LL = (C \text{ wipes per day})(0.04 \text{ lb/wipe})$$
$$\underline{LL = 0.04C}$$

Initial and 180-day resupply period spares weight (SI and SR in lb) Figures 4-20 and 4-21

$$FW = (26.3 + 4.3/P^{0.25})N$$

$$FV = 3.5N$$

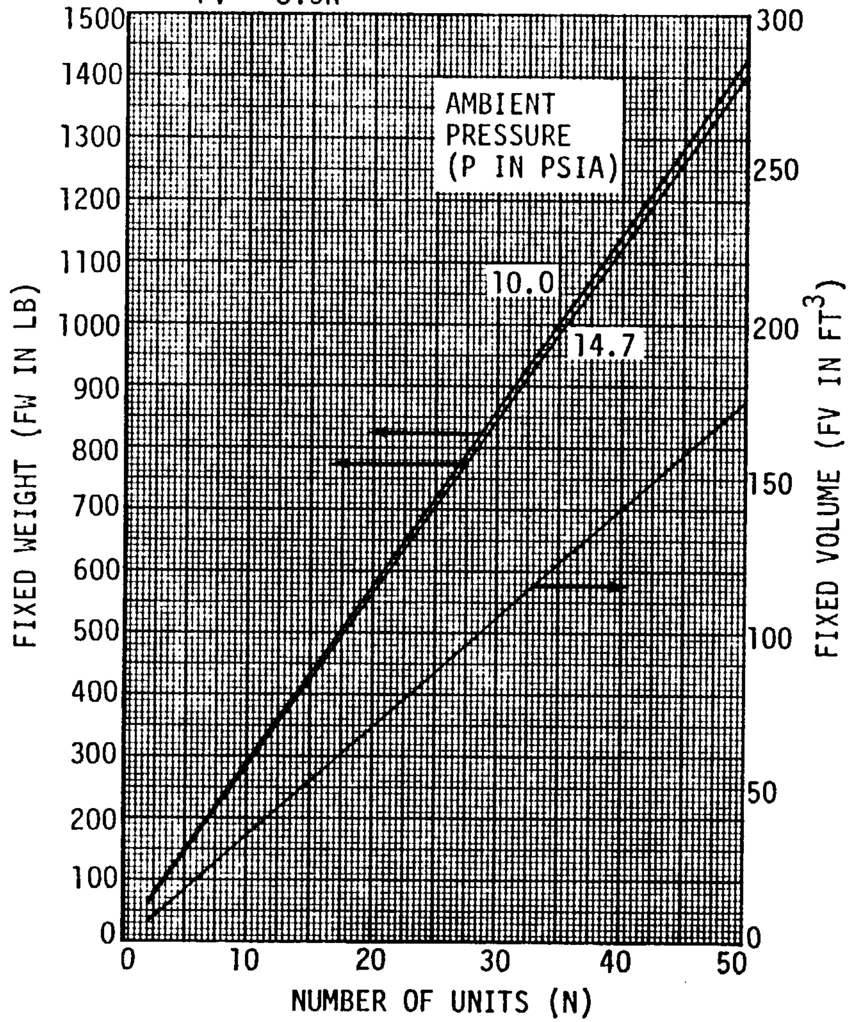


Figure 4-17. Wipe Wetting System Fixed Weight and Volume

$$PM = 35.0 + 533.0/P^{0.5}$$

$$Q_{CP} = 18.1/P^{0.5}$$

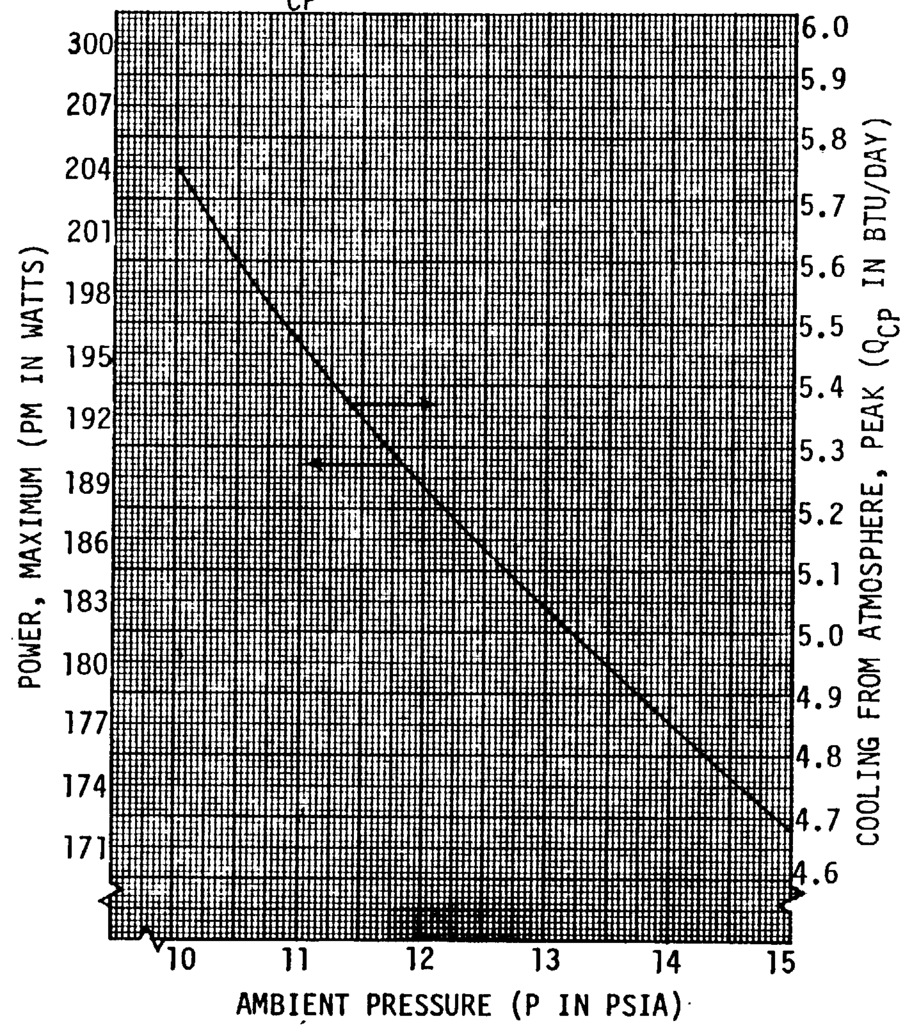


Figure 4-18. Wipe Wetting System Maximum Power and Cooling from Atmosphere

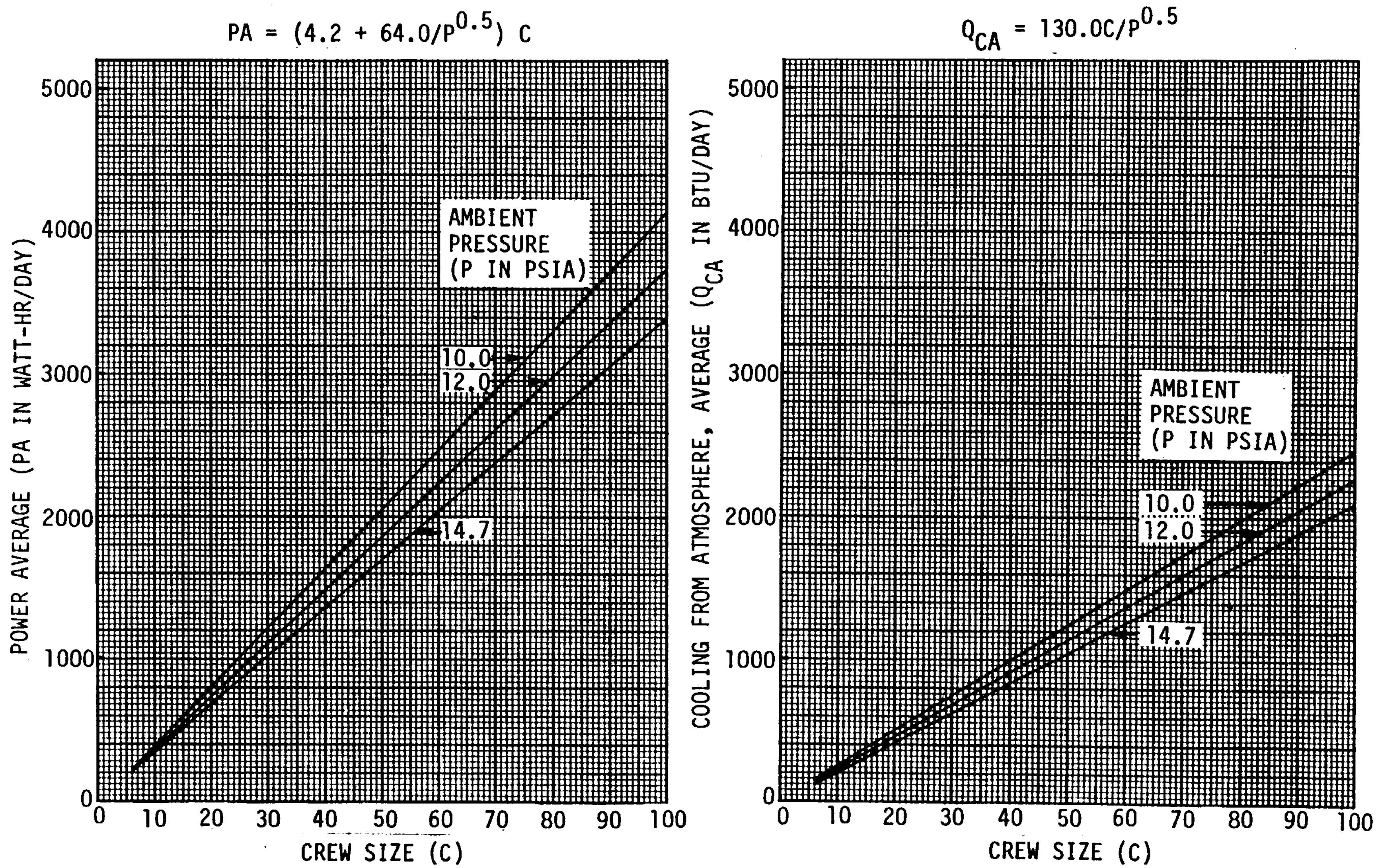


Figure 4-19. Reusable Wet Wipe Wetter Unit Average Power and Average Cooling from Atmosphere

Equation Provided in Paragraph A.6.2 of Appendix A

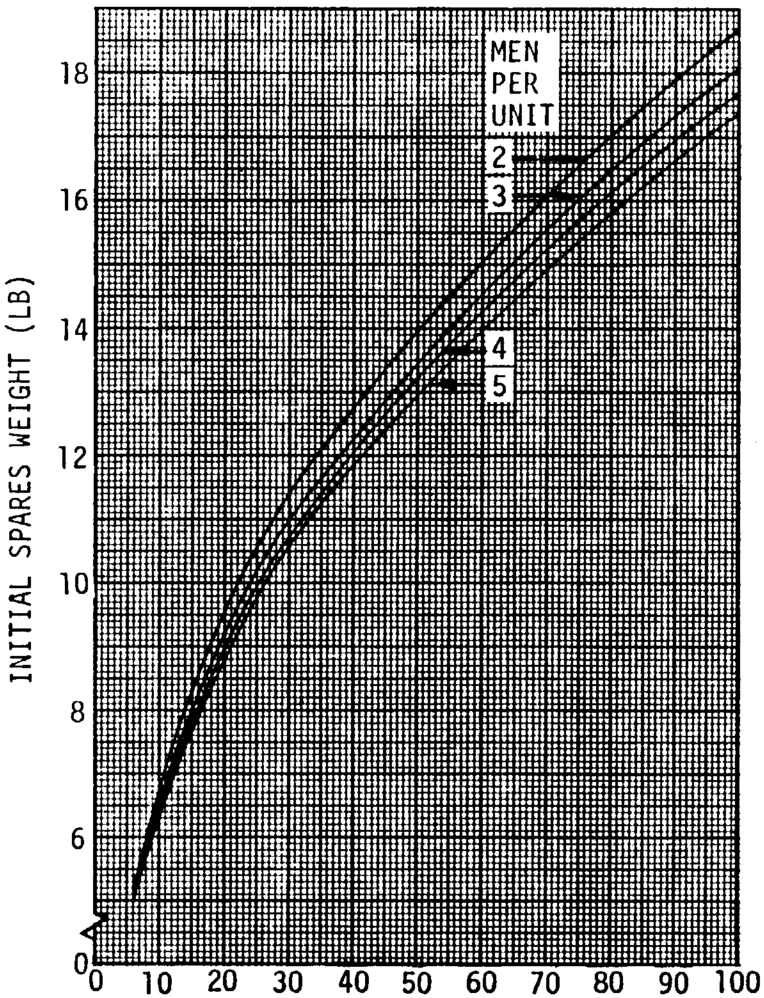


Figure 4-20. Reusable Wet Wipe Wetter Unit Initial Spares Weight

Equation Provided in Paragraph A.6.3 of Appendix A

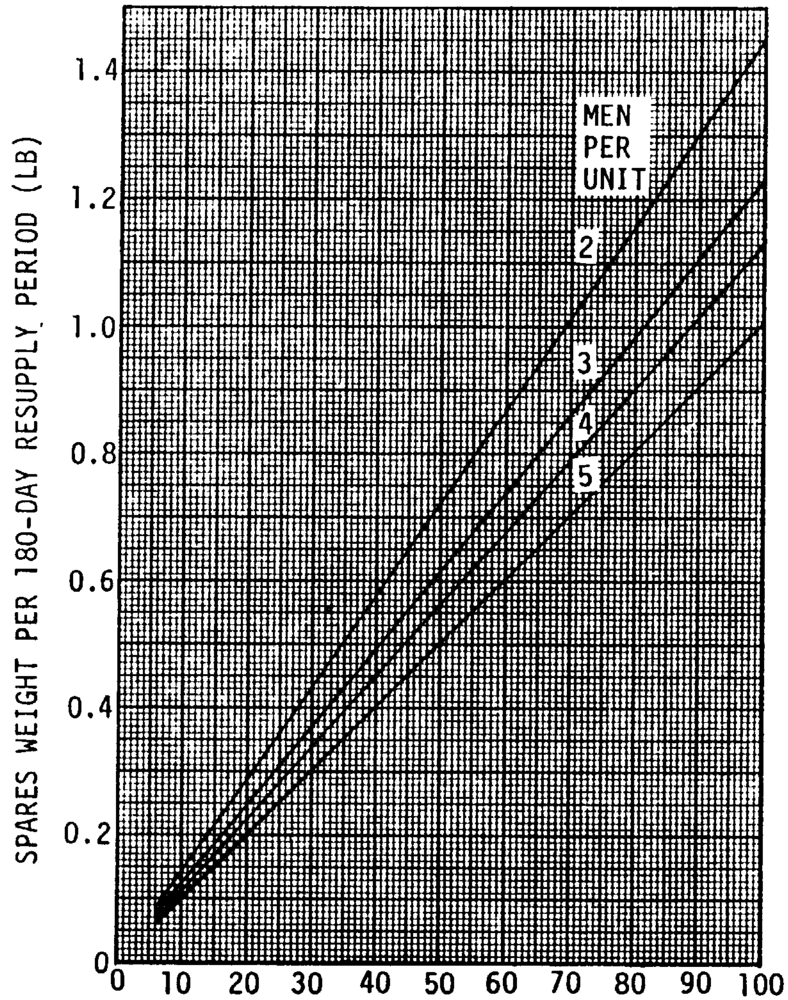


Figure 4-21. Reusable Wet Wipe Wetter Unit Resupply Period Spares Weight

Disposable Wet Wipes

A sponge bath technique using disposable paper wipes can be used to clean local areas. The wipes are used in conjunction with the wipe wetting system shown in Figure 4-16. No laundering is required for disposable wipes since they are discarded wet, dried in a vacuum drier, and returned to earth. Ten of the wipes, which are 12-inch squares of 4-ply "wet strength" paper, are supplied per man per day.

Disposable Wet Wipes Engineering Data

Fixed Weight (FW in lb)		Figure 4-22
Wetter unit (See Reusable Wet-Wipe Data)	$(26.3+4.3/P^{0.25})N$	
Dispenser	$1.152N$	
Cabinet	$0.03CR$	
Collector/dryer	$5.0N+1.5C$	
Total FW =	$(32.5+4.3/P^{0.25})N+(1.5+0.03R)C$	
Fixed Volume (FV in ft^3)		Figure 4-22
Wetter unit (See Reusable Wet-Wipe Data)	$3.5N$	
Dispenser	$1.0N$	
Cabinet	$0.026CR$	
Collector/dryer	$0.5C+1.0N$	
Total FV =	$5.5N+(0.5+0.026R)C$	

Expendable Weight (EW in lb/day)

Wipes

$EW = 0.15C$

Expendable Volume (EV in ft^3/day)

Wipes

$EV = 0.015C$

Atmosphere Lost (AL in lb/day) — Figure 4-23

Venting loss:

AL_V = (volume vented per use)(use rate)(gas density)

$AL_V = 0.5C(1.0 \text{ uses}/7.0 \text{ days})0.0051P$

$AL_V = 0.00037CP$

Leakage loss:

AL_L = (leakage rate per unit)(use rate)N

$AL_L = (0.00072P \text{ lb/hour/unit})(7.0 \text{ hours}/7.0 \text{ days})N$

$AL_L = 0.00072PN$

$AL = (3.7C+7.2N)P/10^4$

Power, Maximum (PM in watts) | Figure 4-24

See Reusable Wet-Wipe Data

$\underline{PM = 35.0+533.0/P^{0.5}}$

Power, Average (PA in watt-hours/day) | Figure 4-25

See Reusable Wet-Wipe Data

$\underline{PA = (4.2+64.0/P^{0.5})C}$

Water Influx from WMS (WI in lb/day)

See Reusable Wet-Wipe Data

$\underline{WI = 5.0C}$

Water Vapor rejected to atmosphere (WV in lb/day)

See Reusable Wet-Wipe Data

$\underline{WV = 0.14C}$

Water Lost (WL in lb/day)

$WL = 62.4\ EV_W/2.0\text{-}EW$

$WL = 0.936C/2.0\text{-}0.15C$

$\underline{WL = 0.453C}$

Water Effluent to WMS (WE in lb/day)

$WE = WI\text{-}WL$

$WE = 5.0C\text{-}0.14C\text{-}0.45C$

$\underline{WE = 4.41C}$

Cooling from liquid loop, Peak (Q_{LP} in Btu/minute)

See Reusable Wet-Wipe Data

$\underline{Q_{LP} = 6.0 \text{ Btu/minute}}$

Cooling from liquid loop, Average (Q_{LA} in Btu/day)

See Reusable Wet-Wipe Data

$\underline{Q_{LA} = 300.0C}$

Cooling from atmosphere, Peak (Q_{CP} in Btu/minute) | Figure 4-24

See Reusable Wet-Wipe Data

$\underline{Q_{CP} = 18.1/P^{0.5}}$

Cooling from atmosphere, Average (Q_{CA} in Btu/day) | Figure 4-25

See Reusable Wet-Wipe Data

$\underline{Q_{CA} = 130.0\ C/P^{0.5}}$

Initial and 180-day resupply period spares weight (SI and SR in lb) | Figures 4-26 and 4-27

$$FW = (32.5 + 4.3/P^{0.25})N + (1.5 + 0.03R)C$$
$$FV = 5.5N + C(0.5 + 0.026R)$$
$$FV \text{ or } FW = \text{Factor A} + \text{Factor B}$$

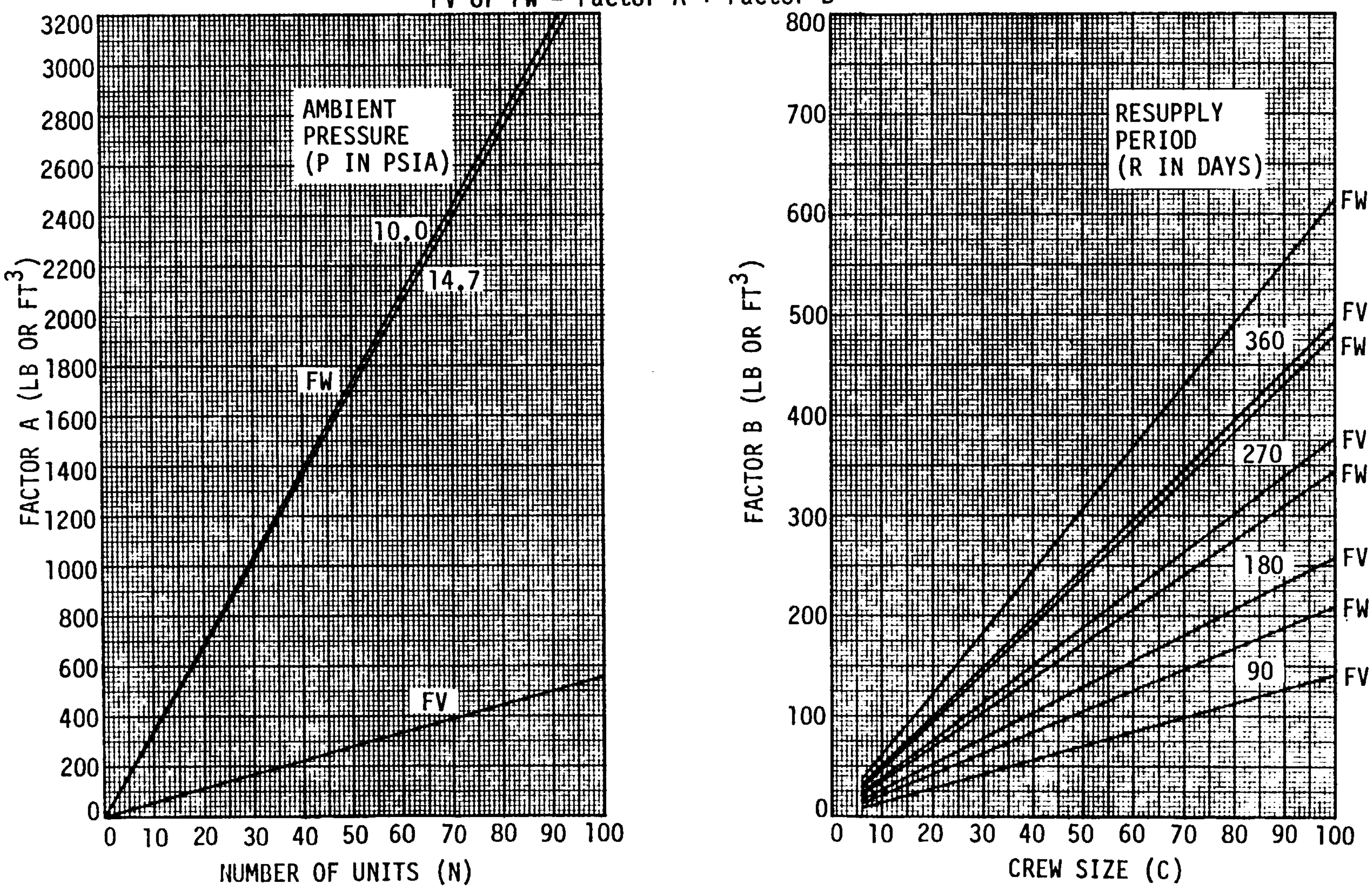


Figure 4-22. Disposable Wet Wipe System Fixed Weight and Volume

$$AL = (7.2N + 3.7C)\ P/10^4$$
$$AL = \text{Factor A} + \text{Factor B}$$

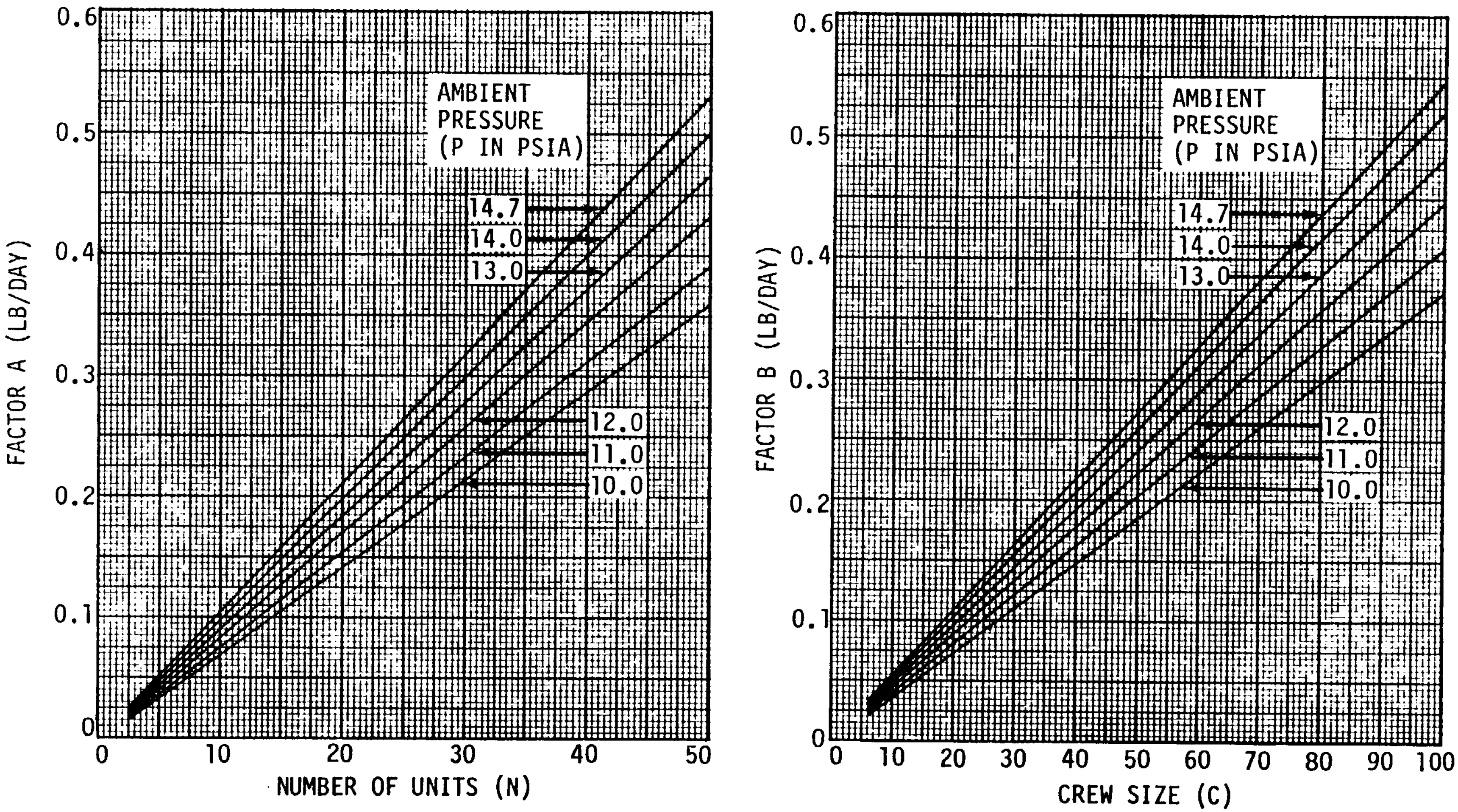


Figure 4-23. Disposable Wet Wipe System Atmosphere Lost During Drying

$$PM = 35.0 + 533.0/P^{0.5}$$

$$Q_{CP} = 18.1/P^{0.5}$$

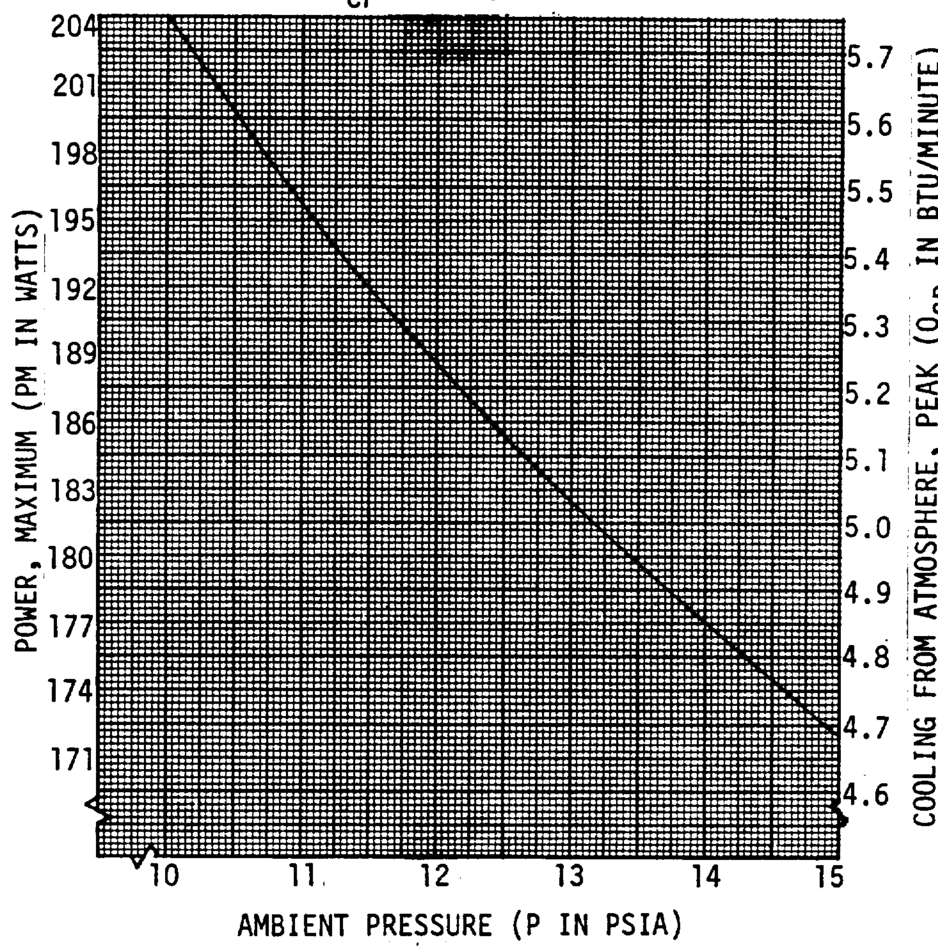


Figure 4-24. Disposable Wet Wipe Wetter Unit Maximum Power and Peak Cooling from Atmosphere

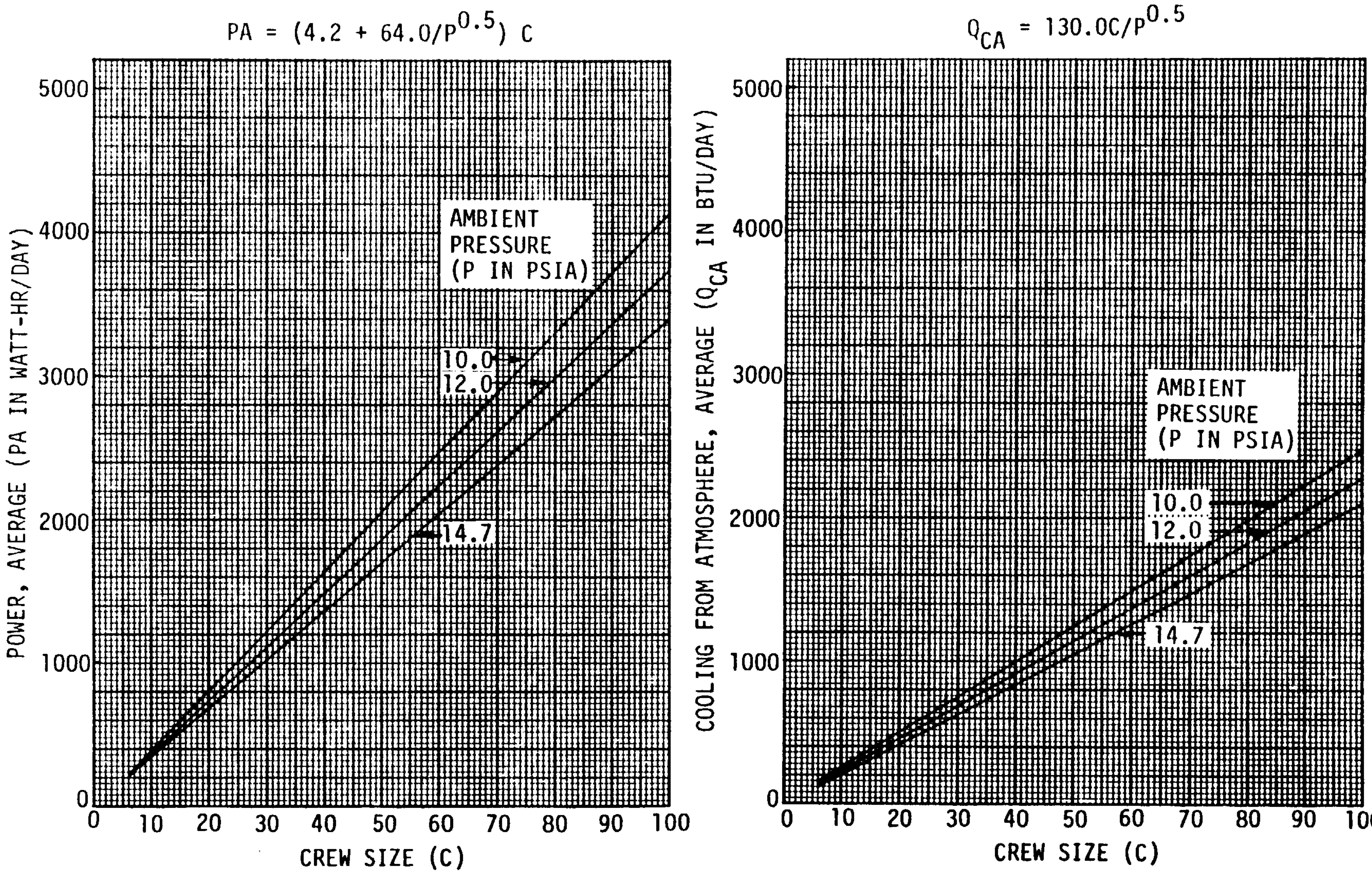


Figure 4-25. Disposable Wet Wipe Wetter Unit Average Power and Average Cooling From Atmosphere

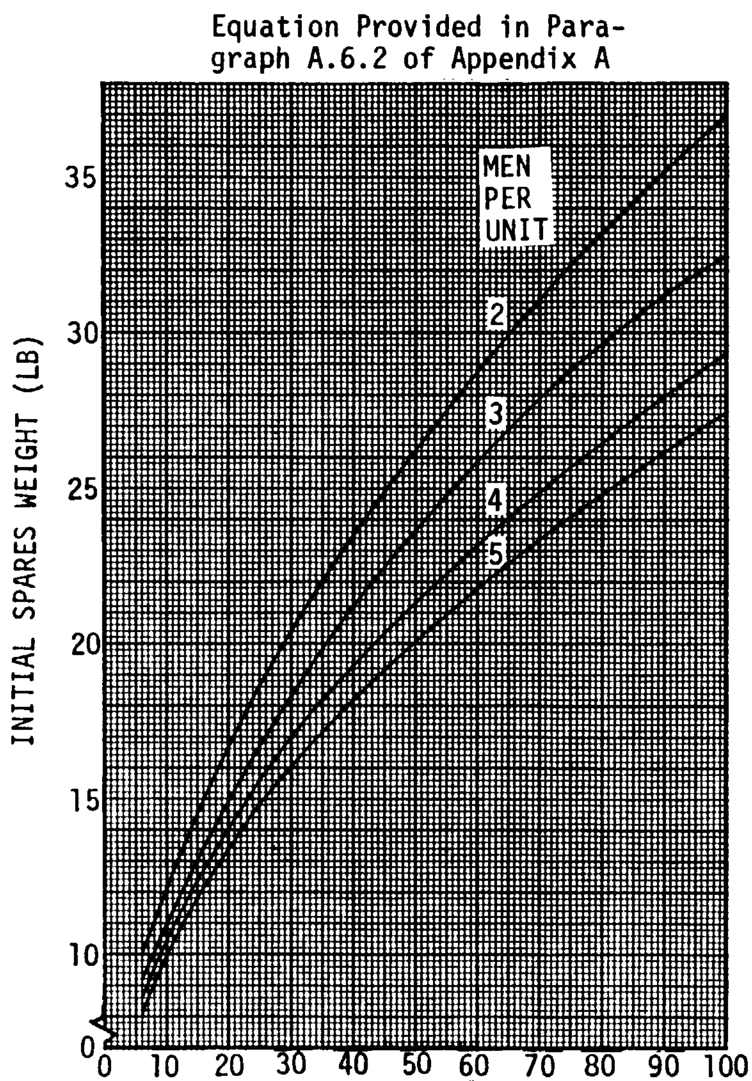


Figure 4-26. Disposable Wet Wipes Wetter Unit Initial Spares Weight

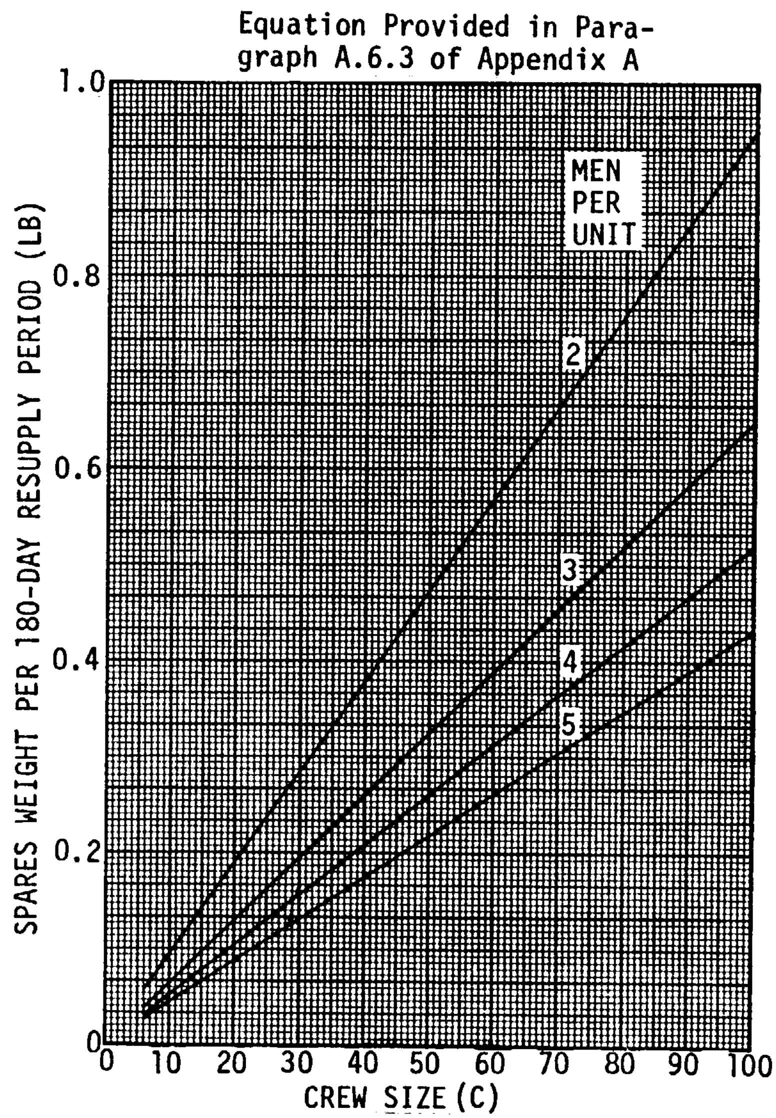


Figure 4-27. Disposable Wet Wipes Wetter Unit Resupply Period Spares Weight

Galley Wipes and Dispensers* (Figure 4-28)

The three types of personal wipes considered for use in the dining area are disposable wipes, reusable wipes, and impregnated cleaning wipes. The wipes will provide for wiping of the mouth and fingers and social amenities during and after meals. The disposable and impregnated cleaning wipes can be stored in dispensers similar to those used in cafeterias.

The dispenser for the reusable wipes is a drawer-type container with integral zero-g retention devices for the contents. The soiled wipes will be laundered and continually reused.

Galley Wipes and Dispenser Engineering Data

Fixed Weight (FW in lb)

Disposable wipe dispenser

<u>FW = 1.48N</u>

Reusable wipe dispenser (drawer)

<u>FW = 2.5N</u>

Disposable impregnated wipe dispenser

<u>FW = 0.8N</u>

Fixed Volume (FV in ft^3)

Disposable wipe dispenser

FV = (6" x 4.75" x 4.25")N/1728

<u>FV = 0.07N</u>

Reusable wipe dispenser (drawer)

FV = (8"x8"x2")N/1728

<u>FV = 0.074N</u>

Disposable impregnated wipe dispenser

FV = (4.25" x 4.25" x 3.25")N/1728

<u>FV = 0.034N</u>

*Data extracted from Reference 6

Expendable Weight (EW in lb/day)

Disposable wipes

$EW = 6(0.0036)C$

$\underline{EW = 0.0216C}$

Reusable wipes

$EW = C(3 \text{ wipes}/90 \text{ days})(0.075 \text{ lb/wipe})$

$\underline{EW = 0.00249C}$

Disposable impregnated wipes

$EW = 3(0.013)C$

$\underline{EW = 0.039C}$

Expendable Volume (EV in ft^3/day)

Disposable wipes

$EV = 6(0.08102/300)C$ (Note: Package of 300 = 0.08102 ft^3)

$\underline{EV = 0.0016C}$

Reusable wipes

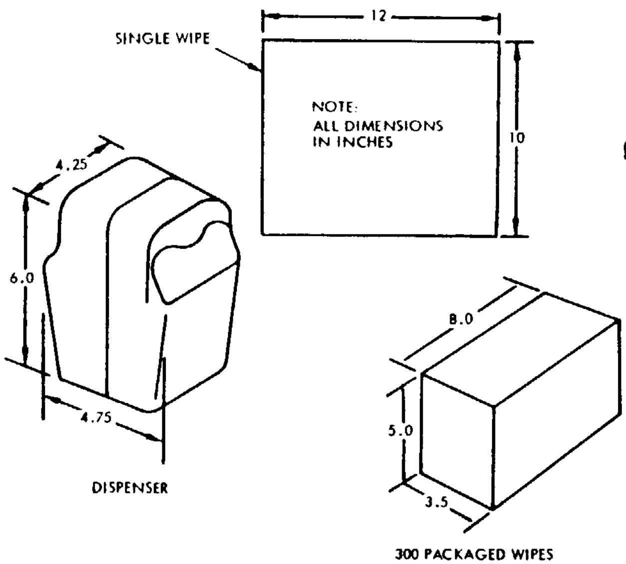
$EV = C(3 \text{ wipes}/90 \text{ days})\ (0.001672 \text{ ft}^3/\text{wipe})$

$\underline{EV = 0.000056C}$

Disposable impregnated wipes

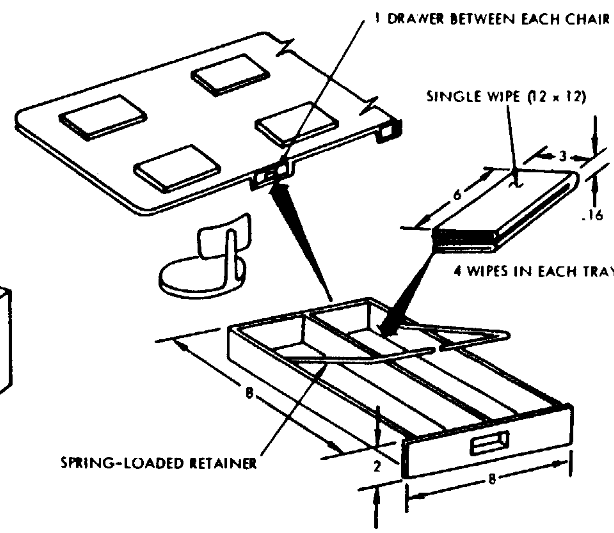
$EV = 3(0.0004884)C$

$\underline{EV = 0.0014652C}$



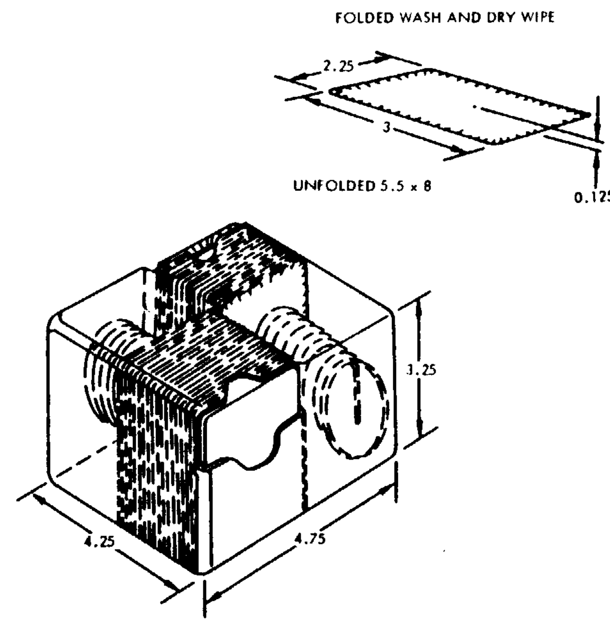
DISPENSER FOR DISPOSABLE PERSONAL WIPES

This unit is similar to a standard earth-type napkin dispenser. It will be of aluminum construction having provisions for internal retention and dispensing of disposable, absorbent paper napkins.



DISPENSER FOR REUSABLE PERSONAL WIPES

This is a compartmented drawer which has a spring-loaded device for the retention of reusable personal napkins. This drawer has a recessed, finger-actuated, light spring force, latching device for positive retention in its closed position.



DISPENSOR FOR DISPOSABLE IMPREGNATED PERSONAL WIPES

This is a box-type enclosure of aluminum construction having provisions for internal retention and dispensing of disposable impregnated cleansing towelettes in individual pocket form. The towelettes are impregnated with a specially developed cleaning solution suitable for use in a space vehicle.

This method provides a means for superficial cleansing of hands and face immediately after completion of the meal which will minimize crew time at lavatory and water reclamation demands.

Figure 4-28. Galley Wipes and Dispensers

4.3 BODY CLEANSING AGENTS

Detergents are grouped into three classes: cationic, anionic, and non-ionic based on how the various detergents react in water.

<u>Cationic</u> - A detergent that hydrolyzes in water to form an acidic solution.

<u>Anionic</u> - A detergent that hydrolyzes in water to form a basic solution.

<u>Non-ionic</u>- This class has two subclasses, amphiprotic and isotonic. Amphiprotic detergents hydrolyze in water to form either basic or acidic solutions; basic if the water is basic, acidic if the water is acidic. Isotonic detergents do not hydrolyze greatly in either basic or acidic water.

In a manned spacecraft, these classes would have the following effects:

<u>Cationic</u> - These detergents, being acidic, will irritate the mucous membranes, e.g., lips, genitalia, eyes, and can cause allergenic reactions if absorbed through the skin (similar to allergenic reactions to tomatoes). They can also form precipitates when used in a basic solution. Precipitates will cause clogging of filters and semipermeable membranes used in the processing equipment. These detergents are frequently added to lubricants, since the cationic polar group attaches to metal surfaces, holding a film of oil to the surface. In a piping system, it would attach to the pipe wall and then build up a coating of waste fats which would eventually clog the pipe.

<u>Anionic</u> - One of the detergents in this class is common soap (sodium palmitate), which has properties typical of all anionic detergents. As with cationics, anionic detergents will irritate the mucous membranes, and can cause allergenic reactions. They will precipitate when used in either an acidic solution or in "hard" water (water containing calcium or magnesium salts).

<u>Non-ionic</u>- These detergents do not cause irritation or allergenic reactions. Isotonic detergents will form precipitates, but only in solutions that are more acidic or basic than will occur on a manned spacecraft. Amphiprotic detergents will not precipitate, even in strong acids or bases.

Either isotonic or amphiprotic non-ionic detergents can be selected for use. The particular detergent selected will depend upon its compatibility with the additives to be used with the detergent (e.g., lanolin, bactericides).

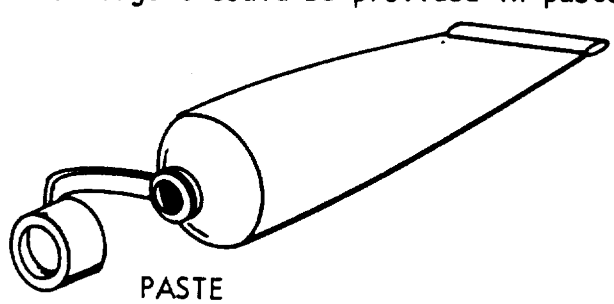
4.3.1 Requirements.

- Cleansing agents shall be good surface active agents (surfactants), or have good "detergent action". Such cleansing agents are, in general, compounds whose molecules have a polar group attached to a relatively long chain hydrocarbon group. They have good detergent action or surface activity, due to the solubility of the polar group in water and of the hydrocarbon chain in grease or oil. A detergent promotes emulsification of insoluble greases because the detergent molecules line up at the grease/water interface, the polar group in the water, and the hydrocarbon group in the grease, thus binding the two phases together.
- The cleansing agents shall be non-flammable, non-explosive, non-odoriferous, and also be compatible with the water processing equipment. This requires that they be: a) effective in low concentrations so that they can be easily removed, b) non-precipitating to prevent clogging of processing and transport equipment, and c) low-foaming to facilitate phase separation.
- The cleansing agents shall be non-toxic if ingested or absorbed through the epidermis, non-allergenic, and non-irritating.

4.3.2 Concept Description and Engineering Data.

Paste Detergent

The particular detergent used to develop engineering data is entsufon (sodium octylphenoxyethoxyethyl ether sulfonate), the non-ionic detergent used in pHisoHex. This is used with just the petrolatum and lanolin additives found in pHisoHex. The hexachlorophene used as a bactericide in pHisoHex is specifically excluded since it has been found (by AMGLO) to form a deposit on semipermeable membranes, causing severe reductions of permeate flow. The detergent could be provided in paste form in tube type containers.



Paste Detergent Engineering Data

Fixed Weight (FW in lb) — Figure 4-29

Storage cabinet (See Appendix A)

FW = 1.152 FV

<u>FW = 0.00058CR</u>

Fixed Volume (FV in ft^3) — Figure 4-29

Storage cabinet

FV = R (EV)

<u>FV = 0.0005CR</u>

Expendable Weight (EW in lb/day)

Tubes of detergent (0.66 lb each)

EW = 0.66C (1.0 tube/30 days)

<u>EW = 0.022C</u>

Expendable Volume (EV in ft^3/day)

Tubes of detergent (0.015 ft^3 each)

EV = 0.015C (1.0 tube/30 days)

<u>EV = 0.0005C</u>

$FW = 0.00058\ CR$

$FV = 0.0005\ CR$

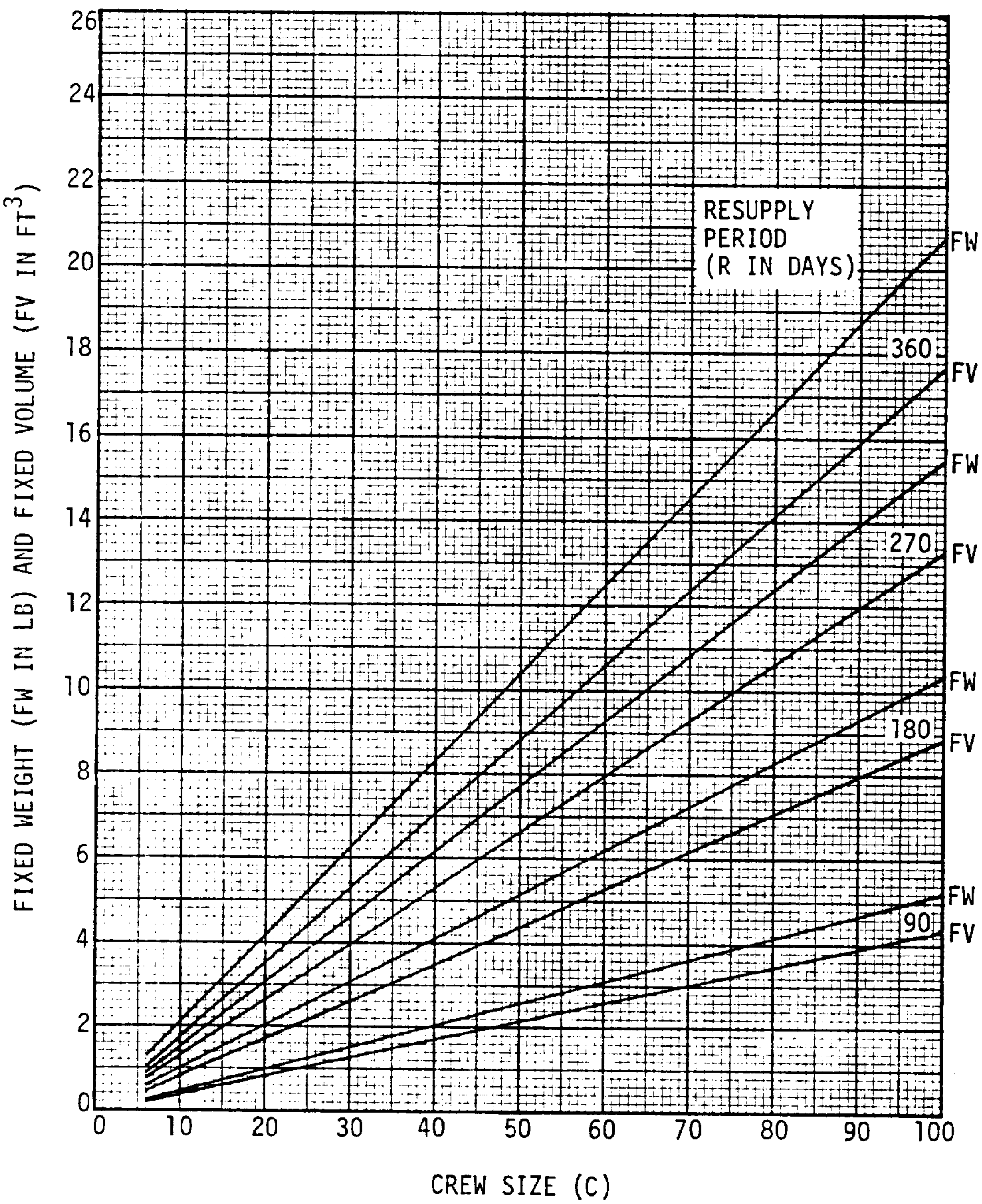


Figure 4-29. Paste Form Detergent Fixed Weight and Volume

4.4 BODY DRYING

4.4.1 Requirements. Refer to the requirements for "Whole Body Cleaning" (Paragraph 4.1.1).

4.4.2 Concept Descriptions and Engineering Data. The body drying concepts discussed in this section are: a) Reusable Full Body Dry Wipes, b) Reusable Local Body Dry Wipes, and c) Disposable Local Body Dry Wipes.

Reusable Full Body Dry Wipes

Terry cloth dry wipes will be used to wipe the skin dry after each full body washing. Each wipe is 30 by 45 inches. A wipe will be used only once (every 3 days), after which it will be washed in the clothes washer. After sixty washes, the wipe will be discarded and replaced. Both spare and clean washed towels are stored in cabinets.

Full Body Drying Engineering Data

Fixed Weight (FW in lb)

Storage cabinet — Figure 4-30

$FW = 1.152(FV)$ (See Appendix A)

$FW = 1.152(0.22+0.00122R)C$

$\underline{FW = C(0.253+0.00141R)}$

Fixed Volume (FV in ft^3) — Figure 4-30

FV = volume of towels in use plus replacements

$FV = (\text{volume per towel})C \text{ towels} + EV_T R$

$\underline{FV = C(0.22+0.00122R)}$

Expendable Weight (EW in lb/day)

Towels (0.54 lb each)

EW = towel weight/service life

$EW = 0.54C/180$

$\underline{EW = 0.003C}$

Expendable Volume (EV in ft^3/day)

Towels (0.22 ft^3 each)

EV = towel volume/service life

$EV = 0.22C/180$

$\underline{EV = 0.00122C}$

Laundry Load (LL in lb/day)

LL = (weight per towel) (towel per day)

$LL = (0.54)\ C/3$

$\underline{LL = 0.18C}$

$$FW = C(0.253 + 0.00141R)$$

$$FV = C(0.22 + 0.00122R)$$

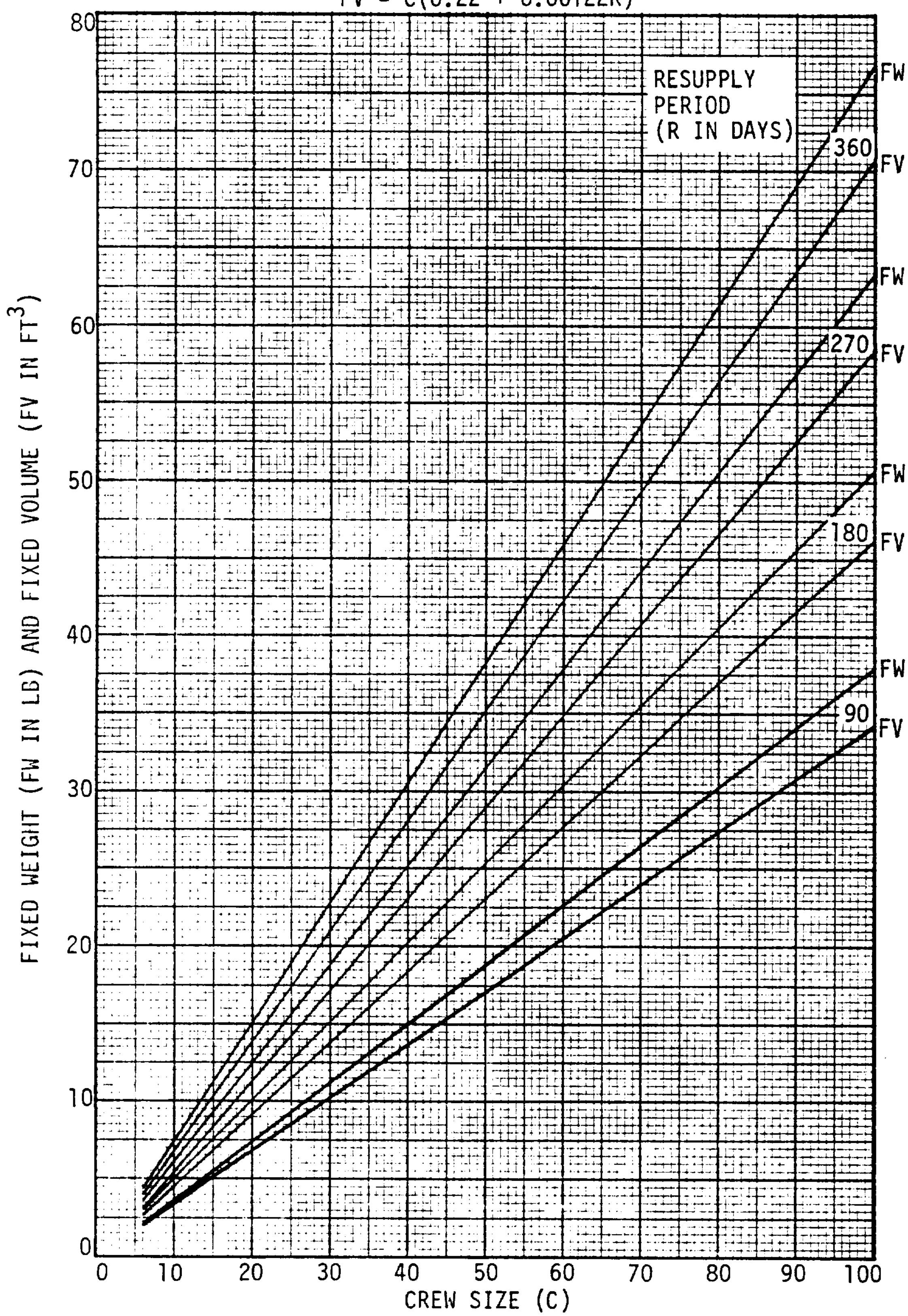


Figure 4-30. Reusable Full Body Dry Wipes Fixed Weight and Volume

Reusable Local Body Dry Wipes

Terry cloth dry wipes will be used to wipe the skin dry after each local body cleaning or hand washing. Each towel is 15 inches by 30 inches and will be used for one day, after which it will be laundered. After sixty washes, the towel will be discarded and replaced. Both new and washed towels are stored in cabinets.

Reusable Dry Wipe Engineering Data

Fixed Weight (FW in lb) Figure 4-31

Storage cabinet

$FW = 1.152\ FV_{SC}$

$FW = 1.152\ (0.146+0.00061R)C$

$\underline{FW = C(0.165+0.0007R)}$

Fixed Volume (FV in ft^3) Figure 4-31

FV = volume of towels in use plus replacements

$FV = (\text{volume per towel})(2C\ \text{towels})+EV_T R$

$FV = (0.073)2C+0.00061R$

$\underline{FV = C(0.146+0.00061R)}$

Expendable Weight (EW in lb/day)

Towels (0.18 lb each)

EW = towel weight/service life

$EW = 0.18C/120$

$\underline{EW = 0.0015C}$

Expendable Volume (EV in lb/day)

Towels (0.073 ft^3 each)

EV = towel volume/service life

$EV = 0.073C/120$

$\underline{EV = 0.00061C}$

Laundry Load (LL in lb/day)

LL = (weight per towel)(towels per day)

$LL = (0.18)C$

$\underline{LL = 0.18C}$

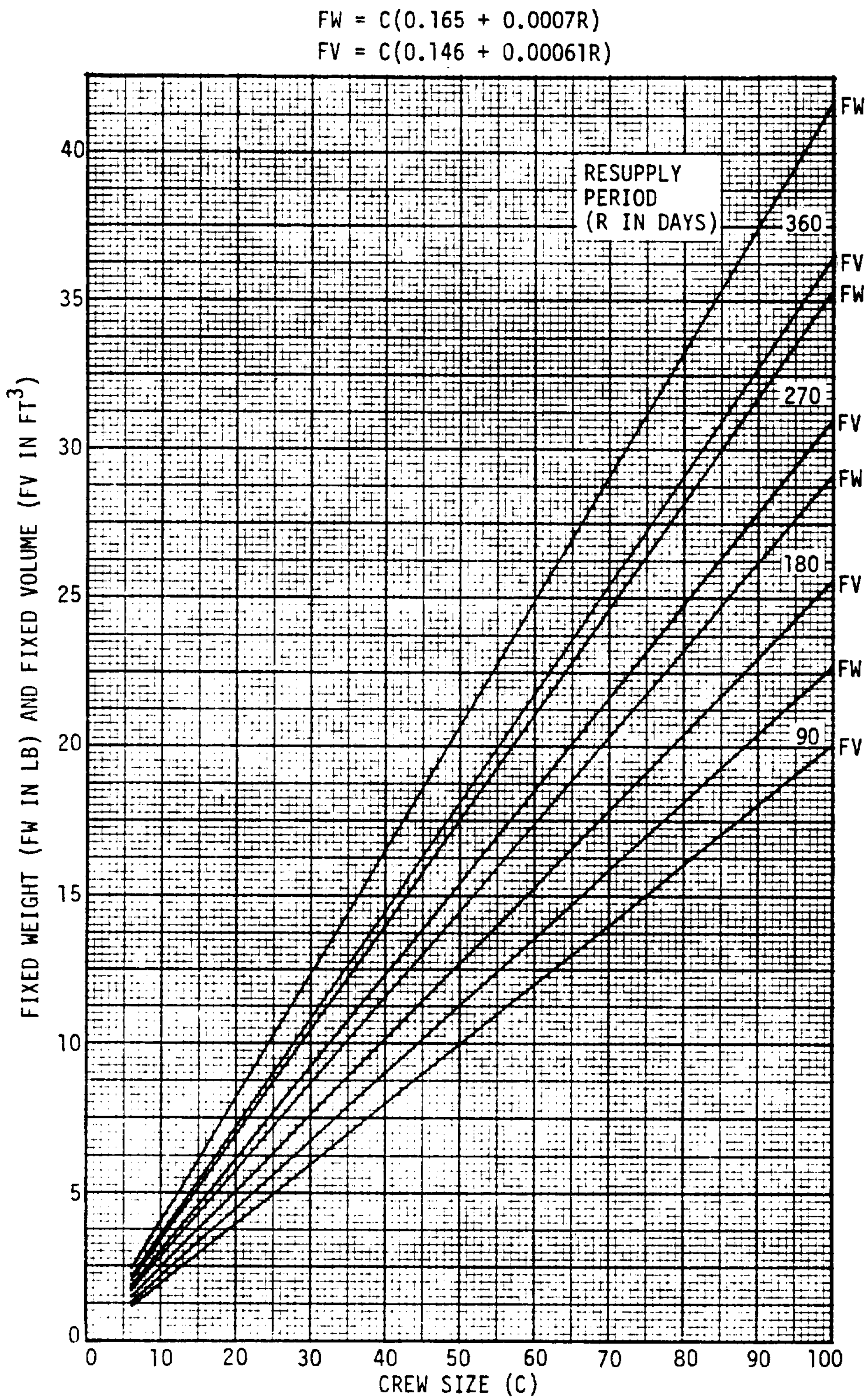


Figure 4-31. Reusable Local Body Dry Wipes Fixed Weight and Volume

Disposable Local Body Dry Wipes

Paper dry wipes will be used to wipe the skin dry after each local body cleaning or hand washing. Dispensers will be provided in each bathroom. Each towel is 12 inches by 18 inches, and is made of four ply "wet-strength" paper. Five towels will be used per man-day. After use, the towels will be discarded wet, dried in a vacuum drier and stored in the expendables storage cabinet until they are returned to earth.

Disposable Dry Wipe Engineering Data

Fixed Weight (FW in lb)			Figure 4-32
Dispenser 1.152 FV_D		1.152N	
Cabinet 1.152 FV_C		0.023CR	
Collector/Dryer		<u>1.5C+5N</u>	
	<u>Total FW =</u>	<u>6.152N+C(1.5+0.023R)</u>	
Fixed Volume (FV in ft^3)			Figure 4-33
Dispenser		1.0N	
Cabinet		0.02CR	
Collector/dryer		<u>0.5C+1.0N</u>	
	<u>Total FV =</u>	<u>2.0N+C(0.5+0.02R)</u>	

Expendable Weight (EW in lb/day)

Wipes (0.023 lb each)

$EW = (5C \text{ wipes/day})0.023$

$\underline{EW = 0.115C}$

Expendable Volume (EV in ft^3/day)

Wipes (0.0023 ft^3 each)

$EV_W = (5C \text{ wipes/day})0.0023$

$\underline{EV = 0.0115C}$

Atmosphere Lost (AL in lb/day) — Figure 4-34

See Disposable Wet Wipes Data

$\underline{AL = (3.7C+7.2N)P/10^4}$

Water Lost (WL in lb/day)

$WL = (62.4\ EV_W/2.0)-EW_W$

$WL = 0.36C-0.115C$

$\underline{WL = 0.245C}$

Initial and resupply period spares weight (SI and SR in lbs) — Figures 4-35 and 4-36

$$FW = 6.152N + C(1.5 + 0.023R)$$
$$FW = \text{Factor A} + \text{Factor B}$$

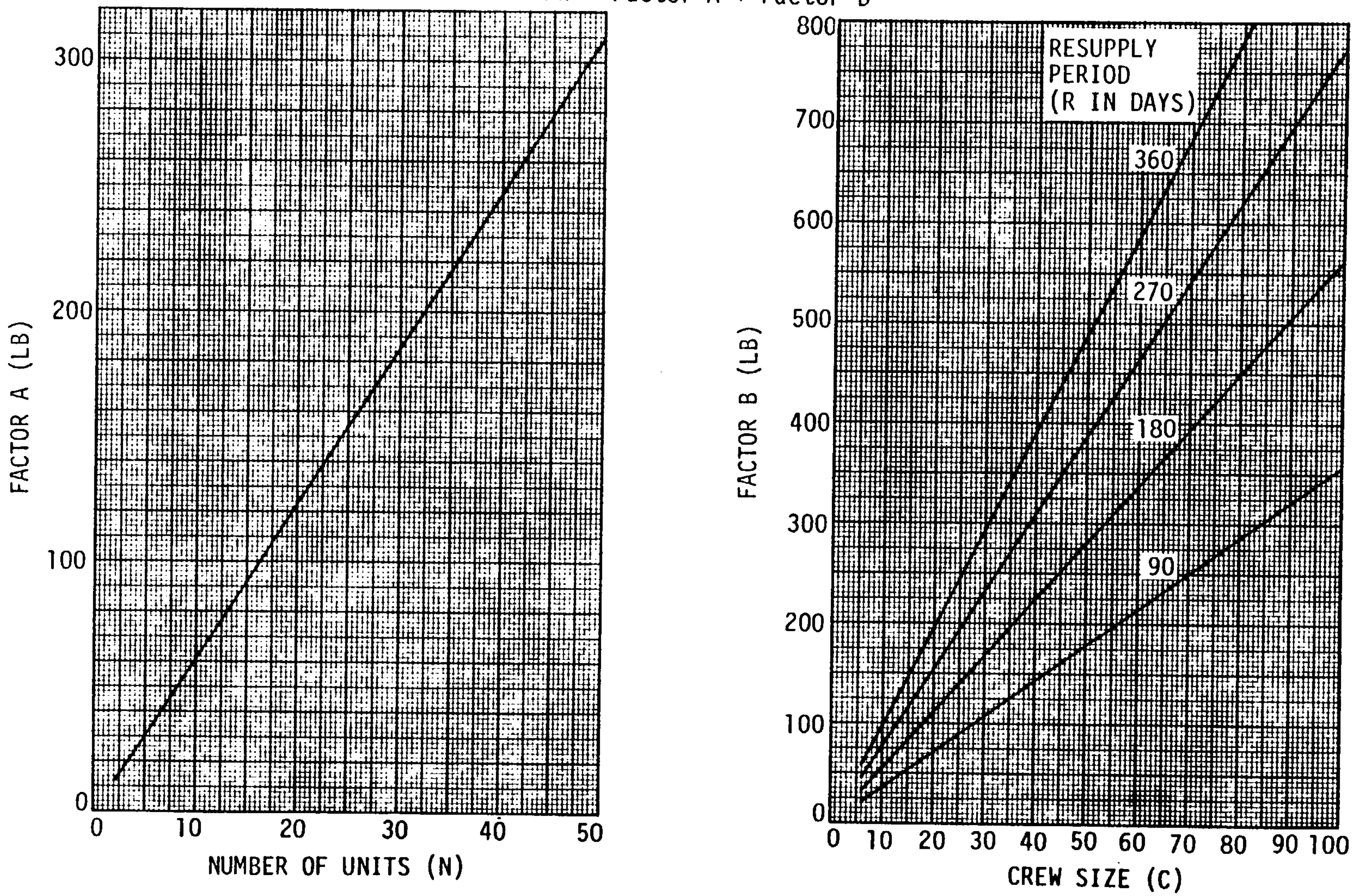


Figure 4-32. Disposable Local Body Dry Wipe System Fixed Weight

$FV = 2.0N + C\,(0.5 + 0.02R)$

$FV = \text{Factor A} + \text{Factor B}$

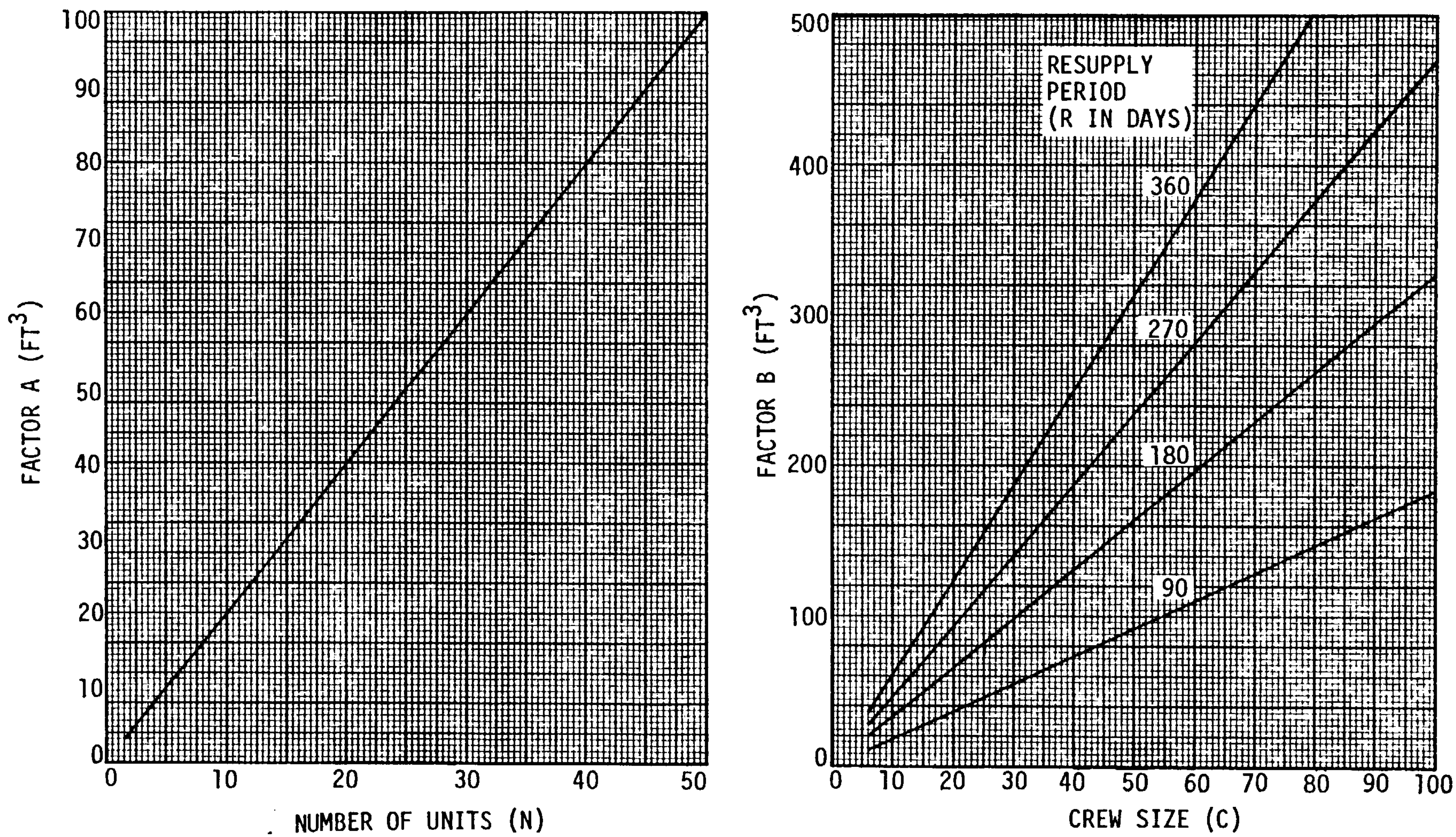


Figure 4-33. Disposable Local Body Dry Wipe System Fixed Volume

$$AL = (7.2N + 3.7C)\,P/10^4$$
$$AL = \text{Factor A} + \text{Factor B}$$

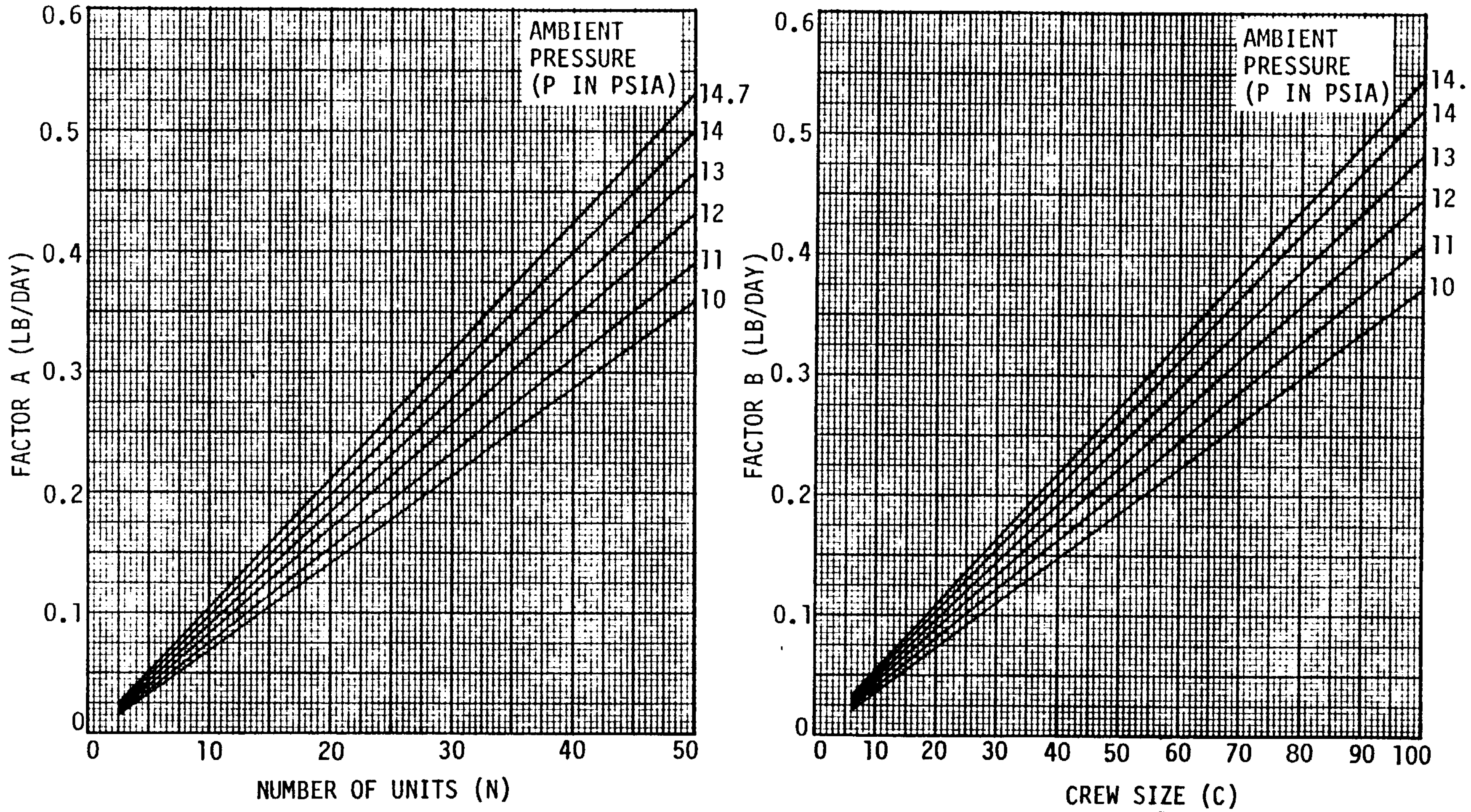


Figure 4-34. Disposable Local Body Dry Wipe System Atmosphere Lost During Drying

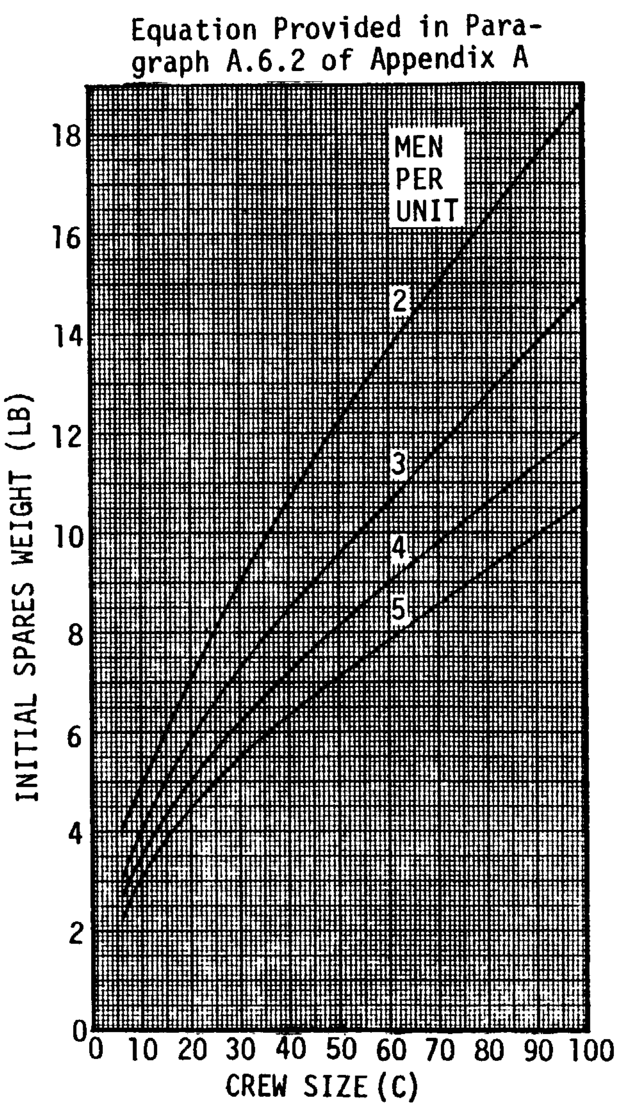


Figure 4-35. Disposable Dry Wipe System Initial Spares Weight

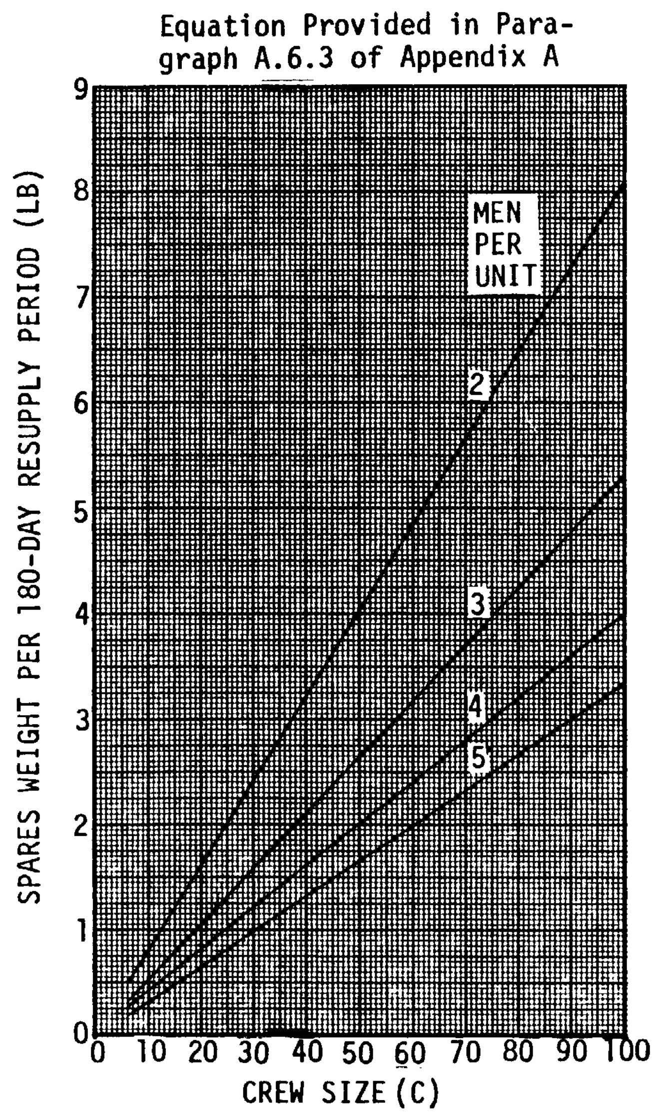


Figure 4-36. Disposable Dry Wipe System Resupply Period Spares Weight

4.5 ORAL CLEANING

4.5.1 Requirements.

- If used, dentifrices should be non-irritating, non-toxic, ingestible, and should contain a fluoride compound.
- Periodontal tissues should not be abraided.

4.5.2 Concept Descriptions and Engineering Data. The oral cleaning concepts discussed in this section are: a) Toothbrush and Dentifrice, b) Dental Floss, c) Water Pik, and d) Ultrasonic Cleaning.

Toothbrush with Dentifrice Followed by Flush with Mouthwash (Tooth Surface Cleaning)

Individual toothbrushes, dentifrice (made ingestible to be non-hazardous if accidentally swallowed), and mouthwash will be supplied to each crewman.

Toothbrush and Dentifrice Engineering Data

Fixed Weight (FW in lb) — Figure 4-37

Toothbrush		0.063C
Holder module		0.4C
Supply cabinet	$= 1.152(FV_{SC})$	
	$= 1.152\ (0.004CR)$	0.0046CR
	Total FW =C(0.463+0.0046R)	

Fixed Volume (FV in ft^3) — Figure 4-38

Toothbrush		0.05C
Holder module		0.1C
Supply cabinet	= (EV)R	0.004CR
	Total FV =C(0.15+0.004R)	

Expendable Weight (EW in lb/day)

Mouthwash	= (lb/use)(use)	
	= (0.0313)4C	0.125C
Dentifrice	= (0.00625 lb/use)4C	0.025C
	Total EW =	0.15C

Expendable Volume (EV in ft^3/day)

Mouthwash (shape factor = 1.6)

EV_M = 1.6 (EW/density)

= 1.6 (0.125C/66.5) 0.003C

Dentifrice (shape factor = 2.3)

EV_D = 2.3 (EW_D/density)

= 2.3 (0.025C/57.5) <u>0.001C</u>

<u>Total EV = 0.004C</u>

$$FW = C(0.463 + 0.0046R)$$
$$FV = C(0.15 + 0.004R)$$

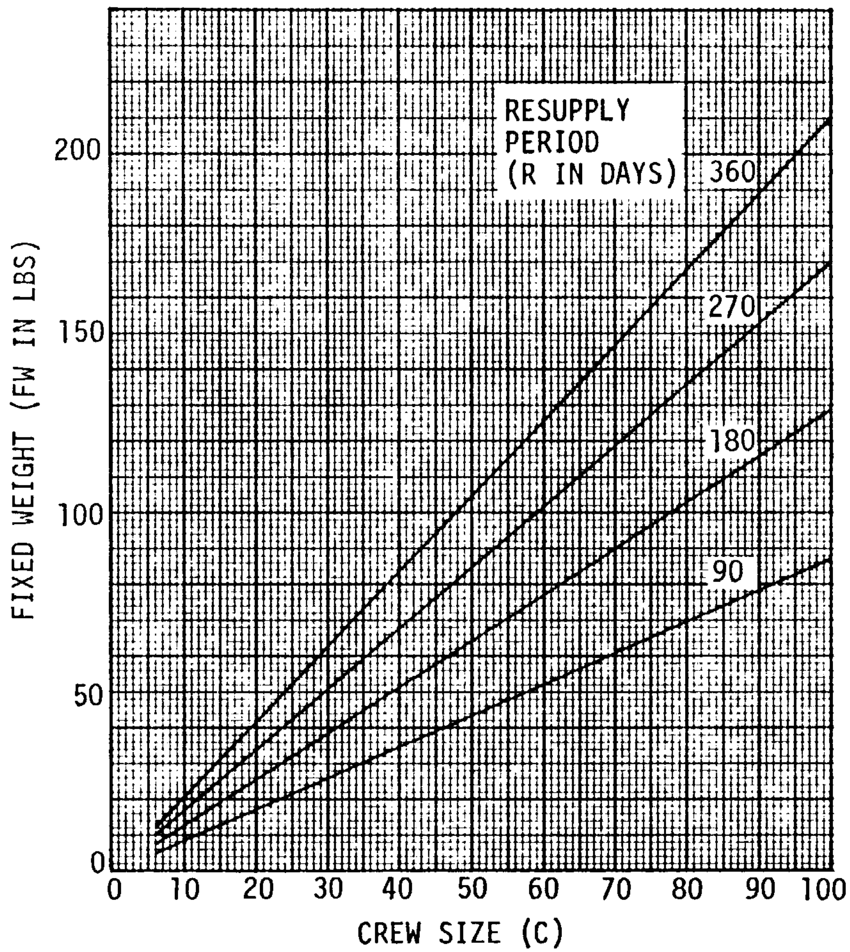


Figure 4-37. Toothpaste, Dentifrice and Mouthwash Fixed Weight

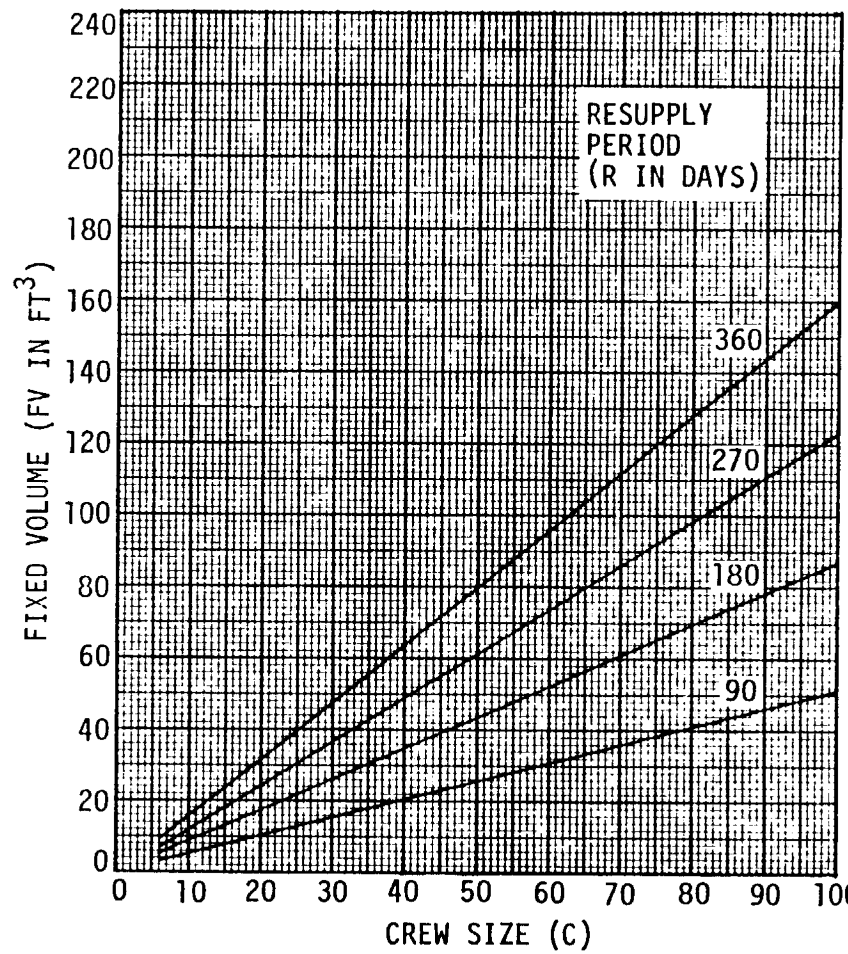


Figure 4-38. Toothpaste, Dentifrice and Mouthwash Fixed Volume

Dental Floss (Crevice Cleaning)

Each crewman may be supplied with a number of 50-foot rolls of dental floss as determined by his tour of duty. The expected use rate is one foot per day.

Dental Floss Engineering Data

Expendable Weight (EW in lb/day)

$EW = (0.07 \text{ lb}/50 \text{ ft roll})(C \text{ ft/day})$

$\underline{EW = 0.0014C}$

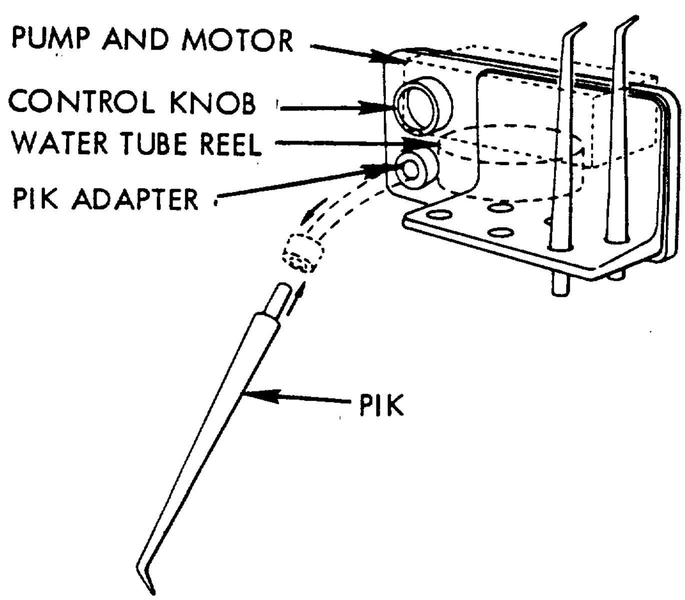
Expendable Volume (EV in ft^3/day)

$EV = (0.02 \text{ ft}^3/50 \text{ ft roll})(C \text{ ft/day})$

$\underline{EV = 0.004C}$

Water Pik (Crevice Cleaning)

A "Water Pik" type unit, with individual tips for each crewman, could be supplied in each bathroom. The unit, connected directly to the water supply line and the power system, would create a high velocity spray to be directed at the tooth crevices to loosen debris.



Water Pik Engineering Data

Fixed Weight (FW in lb)			Figure 4-39
Pump unit		2.7N	
Tips		0.03C	
	Total FW =	2.7N+0.03C	
Fixed Volume (FV in ft^3)			Figure 4-39
Pump unit		0.09N	
Tips		0.0006C	
	Total FV =	0.09N+0.0006C	

Water Influx from WMS (WI in lb/day)

WI = (0.5 lb/use)(C uses/day)

WI = 0.5C

Power, Maximum (PM in watts)

PM = 24.0 watts

Power, Average (PA in watt-hours/day)

PA = PM (use time/day)

PA = 24.0 (0.042C)

PA = 1.0C

Initial and 180-day resupply period spares weight* (SI and SR in lb)

Crew Size	Initial Spares (lb)	Resupply Spares (lb)
6	---	0.003
30	0.3	0.017
60	0.5	0.032
100	0.7	0.054

*Refer to Appendix A for equations and variables

FW = 2.7N + 0.03 C

FV = 0.09N + 0.0006 C

FW or FV = Factor A + Factor B

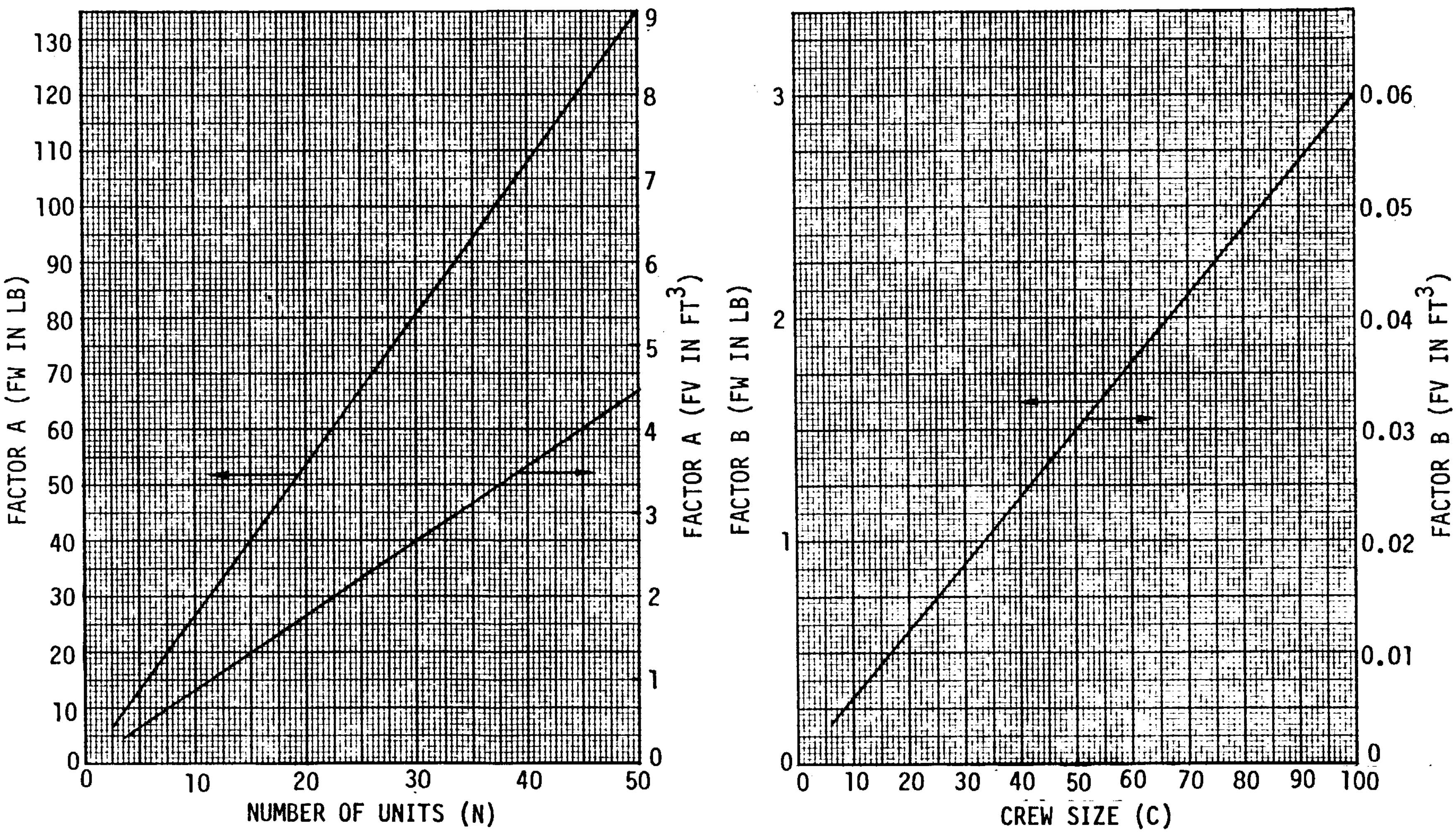


Figure 4-39. Water Pik Fixed Weight and Volume

Ultrasonic Cleaning Device (Plaque and Tartar Removal)

An ultrasonic cleaning device, similar to those a dentist uses, could be supplied for use by a trained dental technician on those crewmen whose stay on-board exceeds 180 days. The unit requires electrical power and cooling provisions to remove waste heat from the ultrasonic transducers.

Ultrasonic Cleaning Device Engineering Data

Fixed Weight (FW in lb)

FW = 50.0 lb

Fixed Volume (FV in ft^3)

FV = 2.0 ft^3

Power, Maximum (PM in watts)

PM = 130.0 watts

Power, Average (PA in watt-hours/day)

PA = 130.0 (0.25 X hours/180 days)

PA = 0.18 X (X = portion of crew whose duty exceeds 180 days)

Cooling from liquid loop, Peak (Q_{LP} in Btu/minute)

Q_{LP} = 7.4 Btu/minute

Cooling from liquid loop, Average (Q_{LA} in Btu/day)

Q_{LA} = 0.62 X

4.6 SCALP HAIR CUTTING AND COLLECTION

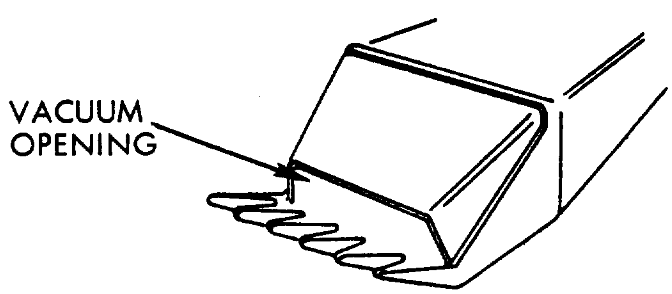
4.6.1 Requirements.

- Scalp hair should be clipped or cut once every 2 to 3 weeks. Cuttings of this period are expected to be 0.17 to 0.25 inch length, and weigh 0.14 to 0.21 ounces.
- Excess hair should be removed, collected, and contained without allowing these wastes to contaminate the cabin atmosphere.

4.6.2 Concept Descriptions and Engineering Data. The scalp hair cutting concepts discussed in this section are the powered clipper and the razor comb.

Powered Clipper with Vacuum Collection

A powered clipper, with the addition of a vacuum collection hood to collect hair clippings, should be used approximately once every two weeks for cutting the hair of each crewman. The clipper is attached to the vacuum cleaner via a flexible hose.



Powered Clipper with Vacuum Collection Engineering Data

Fixed Weight (FW in lb)

Clipper and hood	1.0
Hose and adaptor	1.0
Total FW =	2.0 lb

Fixed Volume (FV in ft^3)

Clipper and accessories in case

$FV = 0.25\ ft^3$

Power, Maximum (PM in watts)

Clipper

PM = 50.0 watts

Power, Average (PA in watt-hours/day)

PA = PM (use time/man-day)C

PA = 50.0 (0.1 hour/14.0 man-days)C

<u>PA = 0.357C</u>

Vacuum Cleaner Use (VU in hours/day)

VU = (use time/man-day)C

VU = (0.1 hour/14.0 man-days)C

<u>VU = 0.0071C</u>

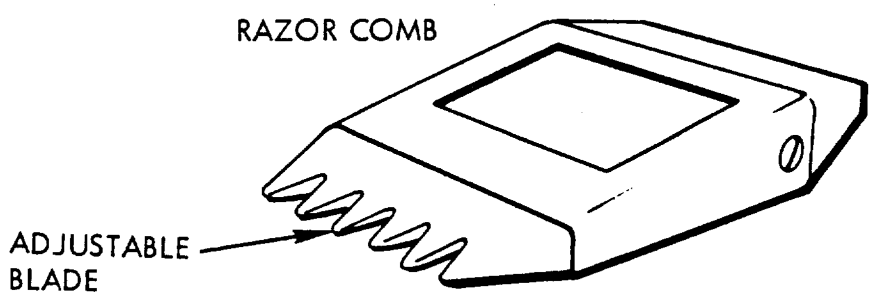
Initial and 180-day resupply spares weight* (SI and SR in lb)

Crew Size	Initial Spares (lb)	Resupply Spares (lb)
6	0.4	0.016
30	1.0	0.078
60	1.5	0.156
100	2.0	0.26

*Refer to Appendix A for equations and variables.

Razor Comb with Vacuum Collection

A razor comb can be used to shave wet hair from the head and hair cuttings collected with a vacuum hose which is attached to the normal debris collection unit.



Razor Comb Engineering Data

Fixed Weight (FW in lb)

Razor comb	0.25
Hose and inlet	1.25
Total FW =	1.5 lb

Fixed Volume (FV in ft^3)

Comb and accessories in case

FW = 0.25 ft^3

Vacuum Cleaner Use (VU in hours/day)

VU = (use time/man-day)C

VU = (0.1 hours/14.0 man-days)C

VU = 0.0071C

4.7 FACE SHAVING

4.7.1 Requirements.

- Facial hair should be removed once every 1 to 2 days. Hair growth for this period is expected to be 0.017 to 0.043 inch and weigh 0.0018 to 0.02 ounce.
- Excess hair should be removed, collected, and contained without allowing this waste to contaminate the cabin atmosphere.

4.7.2 Concept Descriptions and Engineering Data.

Wet Shave with Safety Razor and Cream

Shaving cream, supplied in aerosol cans, will be applied manually to the wet face. An injector type safety razor (one per crewman) will be used to shave the excess hair from the face. A special cleaning arm can be mounted on the razor to sweep hair particles and cream from the blade. The following assumptions were used for calculating the engineering data: one shave per man-day, one blade per 3 man-days.

Safety Razor and Cream Engineering Data

Fixed Weight (FW in lb) — Figure 4-40

Razor and case — 0.1C

Storage cabinet

$FW_{SC} = 1.152\ FV_{SC}$

(See Appendix A)

$FW_{SC} = 1.152C\ (0.01+0.00054R) = \underline{C(0.0115+0.00062R)}$

Total FW $= C(0.1115+0.00062R)$

Fixed Volume (FV in ft^3) — Figure 4-41

Razor and case — 0.01C

Storage cabinet = R(EV) — $\underline{0.00054CR}$

Total FV $= C(0.01+0.00054R)$

Expendable Weight (EW in lb/day)

Cans of lather (1.1 lb each)

$EW_{CL} = 1.1C\ (1.0\ \text{can}/60.0\ \text{days})$

$EW_{CL} = 0.018C$

Blade Injector (0.0625 lb each; 10 blades in pack)

$EW_{BI} = C(0.0625\ \text{lb/injector})(1.0\ \text{injector}/30.0\ \text{man-days})$

$EW_{BI} = 0.002C$

$\underline{EW = 0.02C}$

Expendable Volume (EV in ft^3/day)

Cans of lather (0.0312 ft^3 each)

$EV_{CL} = C(0.0312\ ft^3/1.0\ \text{can})(1.0\ \text{can}/60\ \text{man-days})$

$EV_{CL} = 0.00052C$

Blade injectors (0.00053 ft^3 each)

$EV_{BI} = C(0.00058\ ft^3/\text{injector})(1.0\ \text{injector}/30\ \text{man-days})$

$EV_{BI} = 0.00002C$

$\underline{EV = 0.00054C}$

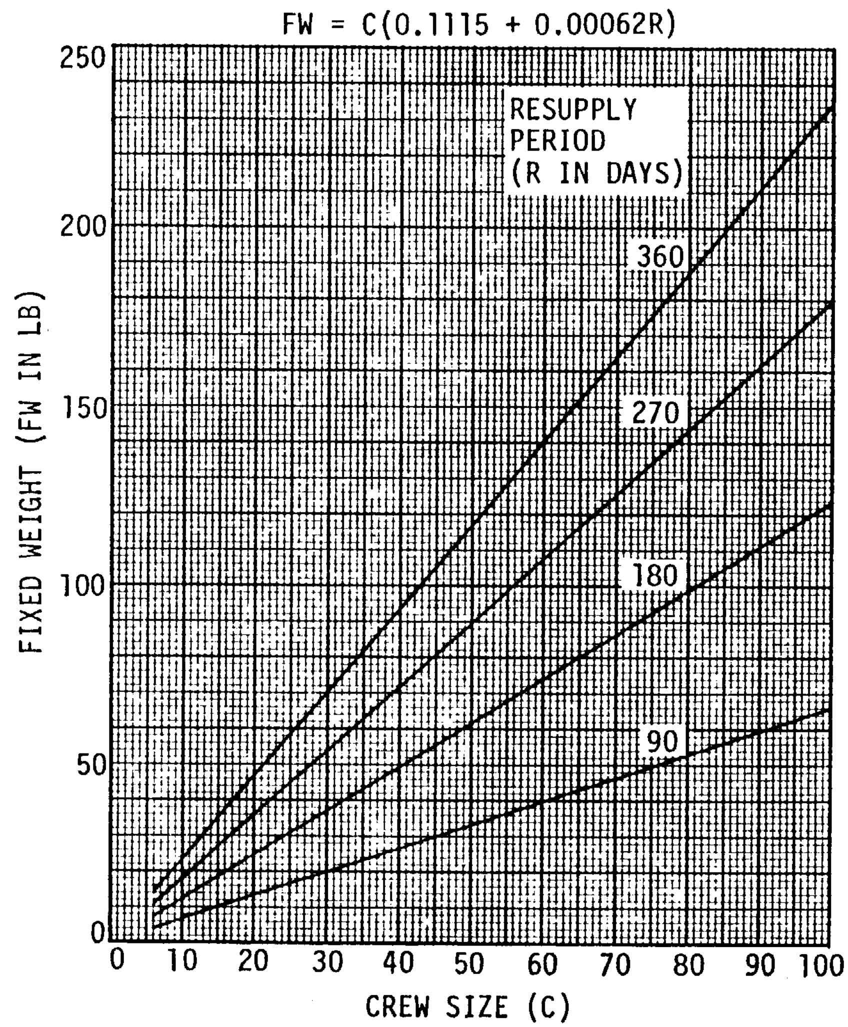


Figure 4-40. Safety Razor and Cream Fixed Weight

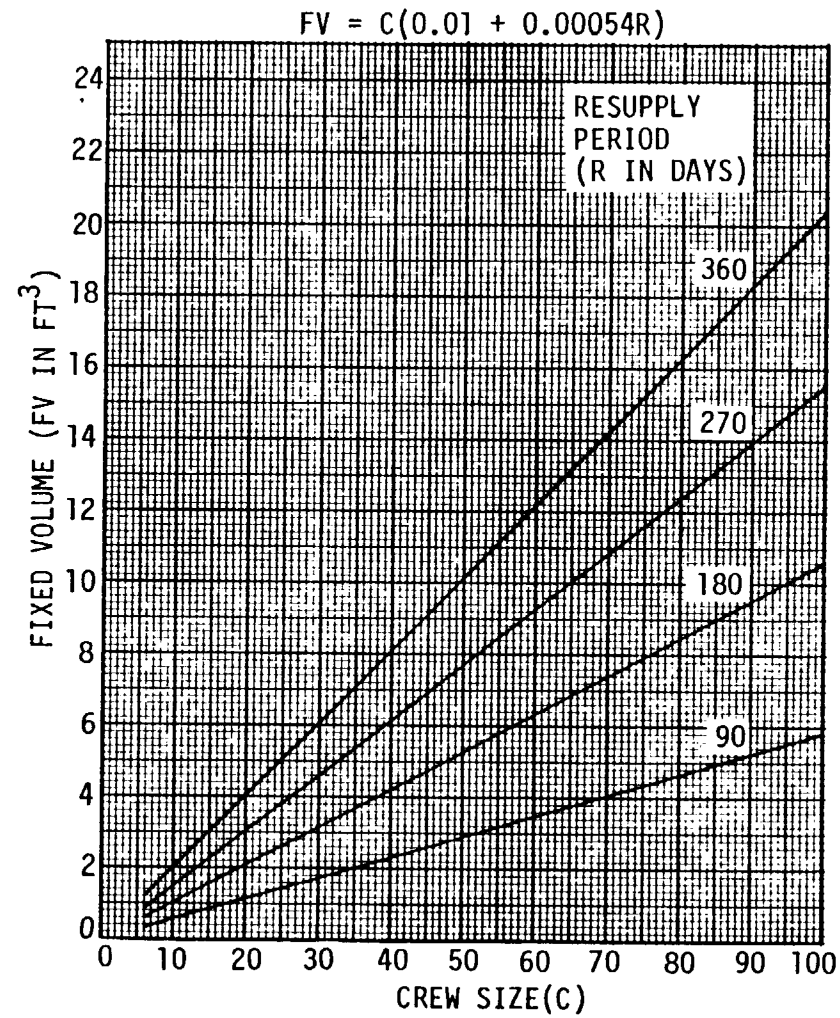
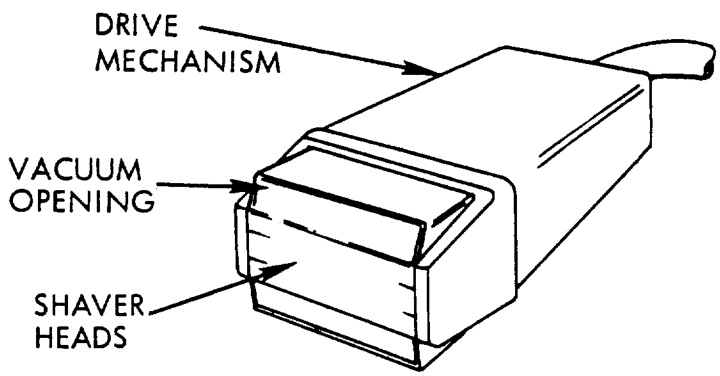


Figure 4-41. Safety Razor and Cream Fixed Volume

Electric Razor with Vacuum Collection

An electric razor with vacuum collection hood is used to shave the facial hair and cut hair is transferred to the collection source by a hose.



Electric Razor with Vacuum Collection Engineering Data

Fixed Weight (FW in lb)

Shaver and hood	0.5C
Hose and adaptor	0.5C
Total FW =	1.0C

Fixed Volume (FV in ft^3)

Shaver and accessories in case

FV = 0.1C

Power, Maximum (PM in watts)

Shaver

PM = 30.0 watts

Power, Average (PA in watt-hours/day)

Shaver

PA = PM (time used/man-day)C

PA = 30.0 (0.1)C

PA = 3.0C

Vacuum Cleaner Use (VU in hours/day)

VU = (use time/man-day)C

VU = (0.1 hour/man day)C

<u>VU = 0.1C</u>

Initial and 180-day resupply period spares weight* (SI and SR in lb)

Crew Size	Initial Spares (lb)	Resupply Spares (lb)
6	1.0	0.103
30	2.0	0.516
60	3.2	1.032
100	4.5	1.72

*Refer to Appendix A for equations and variables

4.8 NAIL CLEANING, TRIMMING, AND COLLECTION

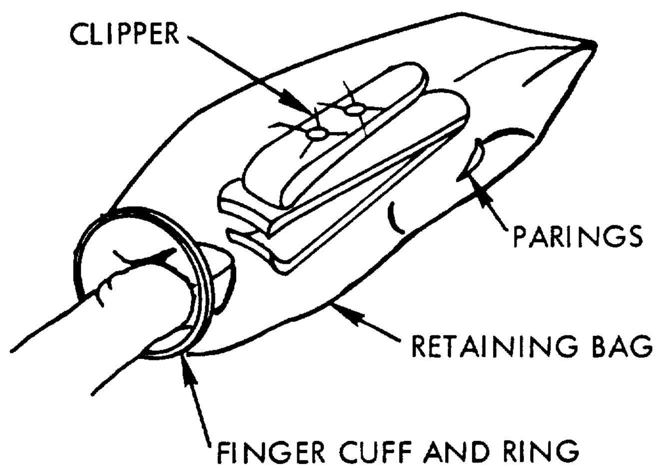
4.8.1 Requirements.

- The free edge of the fingernails should be maintained between 0.04 and 0.12 inch in length. Considering the expected growth rate, frequency of removal should then be once every 10 to 14 days. Weight of parings will be approximately 0.0035 ounce/man every 10 to 14 days.
- The free edge of the toenails should be maintained between 0.04 and 0.12 inch in length. Considering the expected growth rate, frequency of removal should then be once every 4 weeks. Weight of parings will be approximately 0.004 ounce/man every 4 weeks.
- Excess nails should be removed, collected, and contained without allowing these wastes to contaminate the cabin atmosphere.

4.8.2 Concept Description and Engineering Data.

Manual Nail Clipper with Attached Bag

A nail clipper contained in a retaining bag will be used to clip the nails.



Manual Nail Clipper Engineering Data

Fixed Weight (FW in lb)

Bag	0.05C
Clipper	0.03C
Total FW =	0.08C

Fixed Volume (FV in ft^3)

Bag and clipper in case

FV = 0.0002C

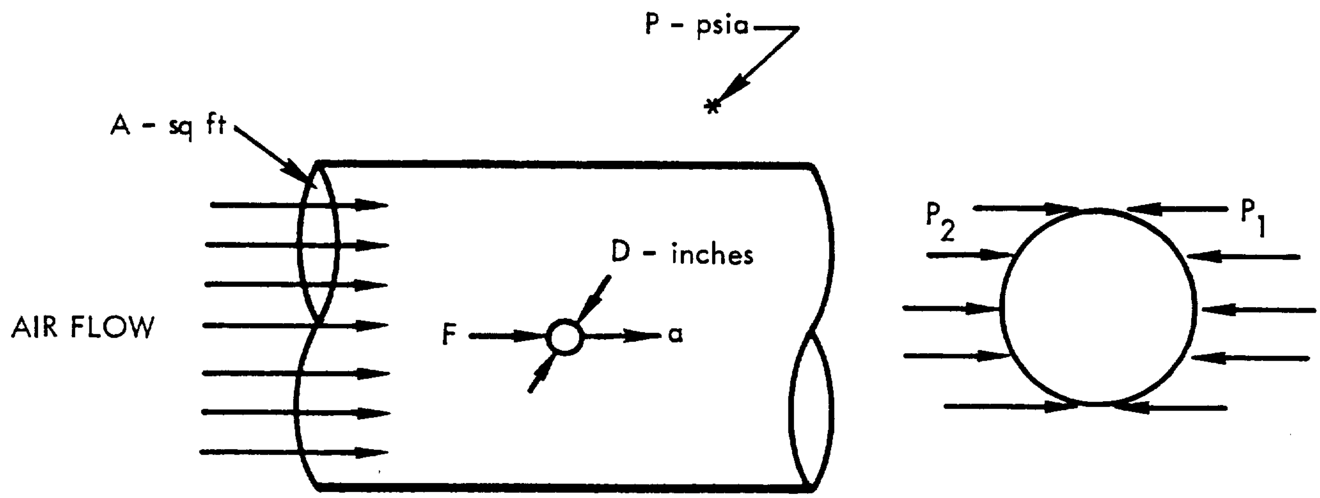
APPENDIX A

SUPPORTING THEORETICAL ANALYSES

A.1 DEVELOPMENT OF RELATIONSHIPS DEFINING THE AIR FLOW REQUIRED FOR ZERO-G AIR TRANSPORT

A.1.1 Equation Development

A droplet "D" inches in diameter, is suspended inside an air duct with a cross-sectional area of "A" square feet. Air flowing in the duct, with static pressure "P" psia, causes the droplet to move with an acceleration of "a" gravities.



Substituting the Bernoulli equation,

$$(P_2 - P_1)/\text{Air Density} = (\text{Air Velocity})^2/2G$$

Into the continuity equation, $Q = (A)\ (\text{Air Velocity})$,

Yields:
$$Q = A\,[2G\,(P_2 - P_1)/\text{Air Density}]^{0.5} \qquad (1)$$

From a free body diagram of the droplet:

$$\text{Force} = (\text{Pressure})\ (\text{Area})$$
$$\text{Force} = (P_2 - P_1)\ (\text{Pi } D^2/4)$$

But from Newton's second law:

$$\text{Force} = (\text{Mass})\ (\text{Acceleration})$$
$$\text{Force} = (\text{Water Density})\ (\text{Pi } D^3/6)a$$

So:
$$(\text{Water Density})\ (\text{Pi } D^3/6)a = (P_2 - P_1)\ (\text{Pi } D^2/4)$$

And:
$$P_2 - P_1 = 0.0241 \text{ Da psi}$$
$$P_2 - P_1 = 3.47 \text{ Da psf} \qquad (2)$$

If temperature is a constant, the Ideal Gas Law shows that

$$P/\text{Air Density} = MRT = \text{Constant}$$

So: $$P/\text{Air Density} = (P/\text{Air Density})_{STP}$$

$$P/\text{Air Density} = 14.7/0.075$$

$$\text{Air Density} = 0.0051P \text{ lb/ft}^3 \quad (3)$$

Substituting equations (2) and (3) into (1)

Yields: $$Q = A\,(2G\ 3.47\ Da/0.0051P)^{0.5}$$

So: $$Q = 209.0A\,(Da/P)^{0.5}\ \text{ft}^3/\text{sec}$$

Or: $$\underline{Q = 12{,}540.0A\,(Da/P)^{0.5}\ \text{cfm}} \quad (4)$$

Where:

Q = Air flow rate, CFM
A = Cross sectional flow area of duct, ft^2
D = Diameter of droplet, inches
P = Ambient pressure, psia
a = Desired acceleration of droplet in gravities

A.1.2 Sample Calculation of Air Flow (see Table A-1 for calculated air flow requirements and assumptions for all air transport units)

For shower assume:

Diameter of shower = 30 inches
Cross sectional area of man = 129 in^2
D = 1/32 inch = 0.03125 inch
P = P psia
a = 1/6 "g"

Calculating A:

A = Area of shower - Area of man

$A = (30.0^2\ Pi/4 - 129.0)/144.0$

$A = 4.0\ ft^2$

Using equation (4) to calculate air flow

$$Q = (12{,}540.0)(4.0)(0.03125/6.0P)^{0.5}$$

$$\underline{Q = 3625/P^{0.5}\ \text{cfm}}$$

Table A-1. Air Flow Requirements

Air Transport Unit	Gross Area (in^2)	Area Blocked (in^2)	A (ft^2)	D (inches)	a ("g")	Q = f (P) (cfm)
Toilets (all)	12.6	0.24	0.086	0.75	0.167	$382.0/P^{0.5}$
Penis seal urinal	5.59	0.79	0.033	0.125	1.0	$147.0/P^{0.5}$
Aperture urinal	0.40	None	0.40	0.125	1.0	$890.0/P^{0.5}$
Shower	705.0	129.0	4.0	0.031	0.167	$3625.0/P^{0.5}$
Hand-held scrubber	0.50	None	0.50	0.031	2.0	$11.0/P^{0.5}$
Wetter unit	158.2	14.2	1.0	0.031	0.167	$906.0/P^{0.5}$

A.2 DIFFERENTIAL PRESSURE CALCULATIONS FOR AIR TRANSPORT UNITS

A.2.1 Assumptions and Methods

"Good design practice" will be used to size components for the specific cabin air pressure selected. Thus, the differential pressure (Delta-P) will be constant with respect to absolute pressure.

The following list indicates the component pressure drops used in calculations.

System Components	Delta-P (in. of water)
Heat exchanger	0.80
Valve in open position	0.15
Bacteria filter	0.40
Coarse filter	0.20
Adsorbent bed	1.00
Water separator	1.50
Ducting (per foot)	0.006
Duct inlet or outlet	0.06
Air jet nozzle ring	1.50

A.2.2 Component Differential Pressures

TOILET SYSTEMS

System Components	Delta-P (in. of water)
Air jet nozzle ring	1.5
Collector plenum	0.06
Coarse filter	0.2
Valve	0.15
Bacteria filter	0.40
Adsorbent bed	1.00
Duct (six feet)	0.036
Duct outlet	0.06
Total	3.406

Delta-P = 3.406 in. of water = 17.7 psf

APERTURE URINAL

System Components	Delta-P (in. of water)
Inlet cone	0.6
Urine separator	1.5
Ducting (six feet)	0.036
Bacteria filter	0.2
Adsorbent bed	1.0
Duct outlet	0.06
Total	3.396

Delta-P = 3.396 in. of water = 17.7 psf

PENIS SEAL URINAL

System Components	Delta-P (in. of water)
Air jet nozzle ring	1.5
Hose (five feet)	0.3
Urine separator	1.5
Bacteria filter	0.4
Adsorbent bed	1.0
Duct (six feet)	0.036
Duct outlet	0.06
Total	4.796

Delta-P = 4.796 in. water = 25 psf

SHOWER

System Components	Delta-P (in. of water)
Stall and man	0.12
Stall inlet and outlet	0.15
Fan housing	0.06
Ducting (10 feet)	0.06
Coarse filter	0.20
Water separator	1.50
Total	2.09

Delta-P = 2.09 in. water = 10.9 psf

HAND-HELD SCRUBBER

System Components	Delta-P (in. of water)
Sponge inlet	4.0
Hose (five feet at 0.1)	0.5
Water separator	1.5
Coarse filter	0.2
Fan outlet	0.06
Ducting (three feet)	0.018
Duct outlet	0.06
Total	6.338

Delta-P = 6.338 in. water = 32.8 psf

WIPE WETTER UNIT

System Components	Delta-P (in. of water)
Inlet to chamber	0.06
Chamber and hands	0.15
Duct outlet	0.06
Ducting (four feet)	0.024
Water separator	1.50
Coarse filter	0.20
Total	1.994

Delta-P = 1.994 in. water = 10.4 psf

A.3 FIXED WEIGHT EQUATIONS

A.3.1 Fans for Air Transport Units

For flight weight axial flow fans, it can be shown by plotting weight versus blade diameter from a Joy catalog, that

$$FW_{Fan} = k(D)^a$$

Where:

k and a are constants, D = blade diameter

From the fan laws: $C_1 = \frac{Q}{\underline{W}D^3}$

$$C_2 = \frac{H}{\underline{W}^2D^2}$$

Where:

$\underline{W}$ = Angular velocity of blade
$\overline{Q}$ = Volume flow of gas
D = Blade diameter
H = Pressure rise = C(Delta-P)/P
P = Ambient pressure

If $\underline{W}$ = Constant (due to noise or electrical power system considerations):

$$H/C_2D^2 = Q^2/C_1{}^2D^6$$

If K = Constant: $K\ D = Q^{0.5}/H^{0.25}$

$$K_2D = Q^{0.5}/(\text{Delta-P}/P)^{0.25}$$

$$K_2D = Q^{0.5}[(P)(\text{Delta-P})]^{0.25}$$

But, for air transport:

$$Q = P(1/P)^{0.5}$$

So: $K_3D = (1/\text{Delta-P})^{0.25}$

Finally: $\underline{FW_{Fan} = K_4\ (1/\text{Delta-P})^{K_5}}$

Which is not a function of absolute pressure.

The fans shown below have been selected from a Joy catalog based on calculated flows and differential pressures.

System	Catalog Number	Weight (lb)
Feces collection systems	X 702-280	3.5
Aperture urinal	X 702-280	3.5
Diaphragm seal urinal	X 702-257	4.0
Shower	X 702-219-A	13.5
Hand-held scrubber	500702-4422	1.6
Wetter unit	X 702-343	3.25

A.3.2 Ducting for Air Transport Units

Calculations

Assume:

a) Air velocity V = 6000.0 ft/min
b) Square ducts are used

c) Ducts are fabricated of aluminum: Rho = 0.1 lb/in^3
d) Metal thickness t = 0.05 inches

$$FW_{Duct} = (Rho)\ (volume\ of\ metal)$$

$$FW_{Duct} = (0.1)\ [0.05(4S)L]$$

$$FW_{Duct} = 0.02\ SL$$

Where:

S = side length of duct

But: $Q = (Area)\ (gas\ velocity)$, and $Area = S^2$

Solving yields: $S = (0.0238Q)^{0.5}$, and $FW_D = (0.003)\ (L\ in.)\ Q^{0.5}$

Finally: $\underline{FW_D = (0.036)\ (L\ ft)Q^{0.5}}$

Ducting Parameters

The following data were generated from the above equation and air flow rates from Table A-1.

Type of Unit	Length/Unit (ft)	Total Length (ft)	FW_D (lb)
Toilets (all)	5.5	5.5N	$3.8N/P^{0.25}$
Penis seal urinal	3.0	3.0N	$1.3N/P^{0.25}$
Aperture urinal	3.0	3.0N	$3.2N/P^{0.25}$
Shower	13.0	13.0N	$28.0N/P^{0.25}$
Wetter unit	4.0	4.0N	$4.3N/P^{0.25}$

A.3.3 Storage Cabinets for Expendables

Assume:

a) Cabinet is square
b) Side length = S
c) Depth is 1.0 foot
d) (S-2) dividers are used on each side
e) Aluminum thickness, t = 0.02 inch

Volume: $(S)(S)(1.0) = S^2\ ft^3$

So: $S = (volume)^{0.5}$

Area:

A = (A of outside surface) + (A of dividers)

$A = (2S^2 + 4S) + 2(S-2)(S)(1.0)$

$A = 4S^2 = 4$ (volume) ft^2

$A = 576$ (volume) in^2

$$FW_{SC} = (Rho)(t)(A) = (0.1)(0.02)(576)(\text{volume})$$

$$\underline{FW_{SC} = (1.152)(\text{volume})}$$

A.4 POWER, MAXIMUM, FOR AIR TRANSPORT FANS

A.4.1 Equation Development

Assume the efficiency of fan/motor combination is 40.0%

$$PM_F = (Q)\ (\text{Delta-P})/0.4$$

$$PM_F = (2.5\ Q)\ (\text{Delta-P})\ \text{ft-lb/min}$$

$$\underline{PM_F = (0.056\ Q)\ (\text{Delta-P})\ \text{watts}}$$

Where:

Q = Air flow rate, in cfm; from Table A-1
Delta-P = Pressure drop of system, in psf, from paragraph A.2
PM_F = Power of fan, in watts

A.4.2 Tabular Data

The maximum power for fans from the different types of air transport units is as follows:

Type of Unit	PM_F (watts)
Toilet systems	$382.0/P^{0.5}$
Penis seal urinal	$208.0/P^{0.5}$
Aperture urinal	$890.0/P^{0.5}$
Shower	$2230.0/P^{0.5}$
Hand-held scrubber	$20.4/P^{0.5}$
Wetter unit	$533.0/P^{0.5}$

A.5 COOLING FROM ATMOSPHERE, PEAK, FOR AIR TRANSPORT UNIT FANS

A.5.1 Equation Development

$$Q_{CP} = PM_F - \text{Fan Air-Power}$$

$$Q_{CP} = PM_F - 0.4\ PM_F$$

$$Q_{CP} = 0.6\ PM_F \text{ watts}$$

$$Q_{CP} = (0.034)\ PM_F \text{Btu/minute}$$

Where:

Q_{CP} = Cooling from atmosphere, peak, in Btu/minute
PM_F = Power, maximum, of fan, in watts

A.5.2 Data Presentation

Individual calculations are shown as part of the engineering data development presented in Sections 3 and 4.

A.6 WEIGHT OF INITIALLY LAUNCHED AND RESUPPLIED SPARES

A.6.1 Assumptions and Rationale

These calculations are based upon a systems reliability goal (time probability of having spares on hand to keep all units of all subsystems operating continually) of 0.95. For each of the 18 hygiene subsystems, the reliability goal is calculated by taking the eighteenth root of 0.95 or 0.9972. The reliability goal for the "C" individual spared elements for each subsystem is the "C^{th}" root of 0.9972 (e.g., if C = 3, the reliability goal for each of the three components is the 3^{rd} root of 0.9972 or 0.9991).

EXAMPLE: If we consider a large space base containing thirty bathrooms with eighteen systems in each, there would be a total of 540 operating units. The systems reliability goal of 0.95 means that there is only five percent chance that one and only one of the 540 units will be inoperative and without spares to effect repair. If this occurs, and one of the 30 shower units is out of commission, the crew would share the remaining 29 units until the next logistics vehicle arrives.

A.6.2 Equation for Initially Launched Spares Weight

The spares allocation assumes that each of N operational units has a failure rate of Lambda (L) with an exponential failure density function. The number of failures thus has a Poisson distribution function such that for each spared element

$$R = \sum_{K=0}^{\$} e^{-NLt}(NLT)^{t}/K!$$

Where:

R = Reliability goal for spared element
$ = Number of spares for each spared element
N = Number of identical spared elements in unit
L = Failure rate of spared element
t = Actual operating time for spared element

The above equation was iterated to find the "$" of each spared element. For any subsystem, the weight of the initially launched spares can then be found from the following equation.

$$SI = \sum_{i=1}^{C} \$_i \, W_i$$

Where:

SI = Initially launched spares weight, lb
$\$_i$ = Number of spares required for the "i^{th}" spared element
W_i = Weight (lb) of a single spare for the "i^{th}" spared element
C = Number of spared elements in the subsystem

The SI of each subsystem has been determined for various crew sizes and unit loading levels using data given in paragraph A.6.4.

A.6.3 Equation for Resupplied Spares Weight

The weight of resupplied spares is the sum of the weight of spares for all spared elements in the subsystem. Thus, the weight of the resupplied spares for any subsystem can be found from the following equation.

$$SR = \sum_{i=1}^{C} (N_i L_i t_i) \, W_i$$

Where:

SR = Spares weight required per resupply period (180 days)

N_i = Number of "i^{th}" spared elements used per unit

L_i = Failure rate of the "i^{th}" spared element

t_i = Actual operating time for the "i^{th}" spared element

W_i = Weight (lb) of a single spare for the "i^{th}" spared element

C = Number of spared elements in the subsystem

The SR of each subsystem has been found for various crew sizes and unit loading levels using data given in paragraph A.6.4.

A.6.4 Data Required to Calculate SI and SR

Spared Element	R	N	$LX10^6$ failures per hour	t (hours)	W (lb)
Chemical Toilet System					
Slinger motor	0.9992	1	5	16C	2.0
Fan/motor	0.9992	1	15	16C	3.5
Chemical injector	0.9992	1	25	4300	4.0
Chemical tank	0.9992	1	75	4300	1.5
"Dry John System"					
Slinger motor	0.9994	1	5	16C	2.0
Vent valve	0.9994	1	25	4300	0.5
Switching valve	0.9994	2	25	4300	0.75
Vacuum pump	0.9994	1	100	8C	1.5
Fan/motor	0.9994	1	15	16C	3.5
Automated Bag System					
Gate valve	0.9996	1	25	4300	3.0
Vacuum pump	0.9996	1	100	8C	1.5
Vent valve	0.9996	1	25	4300	0.5
Heater and control	0.9996	1	70	4300	4.0
Switching valve	0.9996	3	25	4300	0.75
Fan/motor	0.9996	1	15	16C	3.5

Data Required to Calculate SI and SR (Continued)

Spared Element	R	N	$LX10^6$ failures per hour	t (hours)	W (lb)
Penis Seal Urinal					
Seal unit	0.9994	1	25	16C	2.0
Separator	0.9994	1	15	16C	5.0
Fan/motor	0.9994	1	15	16C	5.0
Pump	0.9994	1	30	16C	4.0
Flush valve	0.9994	1	30	4300	1.0
Aperture Urinal					
Separator	0.9993	1	15	16C	5.0
Fan/motor	0.9993	1	15	16C	3.5
Pump	0.9993	1	30	16C	3.0
Flush valve	0.9993	1	30	4300	1.0
Specimen Refrigerator					
Heat pump	0.999	1	12.5	80X	4+2X
Temperature control	0.999	1	25	4300	0.5
Fan/motor	0.999	1	15	4300	0.2
Shower					
Fan/motor	0.9994	1	25	8C	13.5
Valve	0.9994	4	25	8C	1.25
Pump	0.9994	1	30	8C	3.0
Separator	0.9994	1	15	8C	15.0
Accumulator	0.9994	1	3	4300	2.0
Hand-Held Scrubber					
Fan/motor	0.9994	1	15	16C	1.6
Separator	0.9994	1	15	16C	4.0
Pump	0.9994	1	30	16C	3.0
Valve	0.9994	4	25	16C	1.25
Accumulator	0.9994	1	3	4300	1.0

Data Required to Calculate SI and SR (Concluded)

Spared Element	R	N	$L \times 10^6$ failures per hour	t (hours)	W (lb)
Reusable Wet Wipes for Local Body Cleaning					
Fan/motor	0.9994	1	20	10C	3.3
Separator	0.9994	1	15	19C	4.0
Pump	0.9994	1	30	19C	3.0
Valves	0.9994	4	25	19C	1.25
Accumulator	0.9994	1	3	4300	1.0
Disposable Wet Wipes for Local Body Cleaning					
Fan/motor	0.9995	1	20	19C	3.3
Separator	0.9995	1	15	19C	4.0
Pump	0.9995	1	30	19C	3.0
Switching valves	0.9995	4	25	19C	1.25
Vacuum valves	0.9995	2	30	4300	1.25
Accumulator	0.9995	1	3	4300	1.0
Disposable Dry Wipes for Full Body Drying					
Vacuum valve	0.9972	2	30	4300	1.25
Powered Hair Clipper					
Clipper	0.9972	1	500	1.3C	1.0
Electric Razor					
Razor	0.9972	1	500	1.3C	0.5
"Water - Pik"					
Water pik pump	0.9972	1	30	7.5C	2.7

REFERENCES

NOTE

The primary source of data for this Handbook was Reference 1. Concepts extracted from References 2 through 6 are noted in the text.

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